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DC-ARM Final Demonstration Report

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14. ABSTRACT
This report documents the findings of a real-scale experimental study designed to determine the technologies and damage control (DC) doctrine that should be followed to enable major DC manning reductions on future surface combatants. The experiments consisted of a series of real-scale fire tests and technology demonstrations onboard the Navy's full-scale control RDT&E facility, ex-USS *Shadwell* (LSD-15). The damage scenarios consisted of peacetime tests that represented small, but growing fire events and a wartime scenario that represented the damage expected from the detonation of a medium-sized warhead. Radically reduced DC manning concepts that leap-ahead DC system technologies were exercised with Fleet users during this real-scale shipboard study. The study demonstrated that the DC manpower requirements on a modern destroyer-type ship could be significantly reduced from its present manning level of 105 to 45 people with the proper integration of DC system automation and improved DC doctrine (organization and procedures).

15. SUBJECT TERMS
Optimal manning; Multi-criteria sensor array; Water mist; Smoke ejection system; Autonomous smart values; Supervisory control system

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ACRONYMS

1MC	General announcing system
ADC	Advanced Damage Countermeasures
AFFF	Aqueous film-forming foam
AFT	Afloat Training Group
AMR	Auxiliary Machine Room
APDA	Adjacent to primary damage area
BC	Boundary cooling (mode of operation for water mist system)
BDAT	Battle Damage Assessment Team
BRT	Back-up Repair Team
BUMED	Bureau of Medicine and Surgery
CBR	Chemical, biological, and radiological
CIC	Combat Information Center
COTS	Commercial off-the-shelf
CPO	Chief Petty Officer
CPS	Collective protection system
CSMC	Combat System Maintenance Central
DC	Damage Control
DCA	Damage Control Assistant
DC-ARM	Damage Control – Automation for Reduced Manning
DCC	Damage Control Central
DCO	Damage Control Officer
DCRS	Damage Control Repair Station
DNA	Did Not Alarm
DOT&E	Director of Test and Evaluation
ECAT	Engineering Casualty Assistance Team
EMI	Electromagnetic Interference
EWFD	Early-Warning Fire Detector
FDE	Fleet Doctrine Evaluation
FFE	Fire Fighting Ensemble
FNC	Future Naval Capabilities
FS	Fire suppression (mode of operation for water mist system)
FY	Fiscal year
HF	Hydrogen Fluoride
IMO	International Maritime Organization
IR	Infrared
LAN	Local area network
LED	Light emitting diode
MMR	Main Machinery Room
NAVSEA	Naval Sea Systems Command
NFPA	National Fire Protection Association
NRL	Naval Research Laboratory

NSWC	Naval Surface Warfare Center
ODM	Optical density meter
ONR	Office of Naval Research
ORD	Operational Requirement Document
OSD	Office of the Secretary of Defense
PDA	Primary Damage Area
PKP	Purple-K-Powder (potassium bicarbonate)
PNN	Probabilistic Neural Network
RF	Radio frequency
RRT	Rapid Response Team
SCBA	Self-contained breathing apparatus
SCS	Supervisory Control System
SES	Smoke Ejection System
SWOS	Surface Warfare Officers School
TMM	Task Management Module (Module of SCS)
TPES	Total Protection Exhaust System
TPSS	Total Protection Supply System
WET	Weapons Effect Testing
WIFCOM	Wirefree Communication
WMCO	Water Mist Cutout (valve)
WMCV	Water Mist Control Valve

DC-ARM FINAL DEMONSTRATION REPORT

1. BACKGROUND

Economic pressures to reduce the cost of ownership for Navy ships have brought into focus the need to reduce the size of the ship's crew. This focus on reduced crew size has also highlighted the need to study the impact of reduced manning on various crew functions, in particular, the effect reduced crew size will have on damage control readiness. It is generally recognized that the challenges posed by a minimally manned combatant will require a higher level of technology to ensure that mechanisms are in place to augment and/or replace some of the decision making and actions accomplished by crew members aboard ships today. For Damage Control (DC), this expanded use of technology will also mandate a higher level of reliability to ensure that the new automated systems can effectively control the damage resulting from all survivable casualty conditions.

To solve these technical issues, the Office of Naval Research (ONR) (Code 334) has sponsored the Damage Control – Automation for Reduced Manning (DC-ARM) program to develop the technologies necessary to achieve major reductions in DC manning. The DC-ARM program is aimed at developing the technology required for automated shipboard damage assessment and casualty response for timely mitigation of shipboard fire and flooding conditions.

1.1 Terminology

Discussion of the demonstrations requires an understanding of some key terms:

1. Primary damage area (PDA) compartments – These compartments are directly affected by a weapons blast. The bulkhead, decks, or doors within these compartments are breached as a result of the blast overpressure. Thus, there is free communication between all areas of the PDA.

2. Adjacent to primary damage area (APDA) compartments – These compartments border PDA compartments. They share a common boundary (bulkhead, overhead, or deck) with a compartment that is part of the PDA. Combustibles in these compartments have the potential to ignite after PDA compartments reach flashover or as the result of direct fire exposure of the boundary. There is no free communication between the PDA and APDA.

3. Situation awareness – The FY98 test series demonstrated the need for the Damage Control Assistant (DCA) to have improved situation awareness (i.e., knowledge of events) [1]. By having a good understanding of the casualty, the DCA can make decisions related to casualty control and manpower allocation more effectively. Information that contributes to good situation awareness includes identification of fire locations and primary damage areas. Information regarding fire main status, door closure positions, ventilation status, and fire suppression is also important to situation awareness.

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4. Damage Control Officer (DCO) – For the FY01 demonstration, the title of the person in charge of the DC operations was changed from DCA, which was used in FY98 and FY00, to DCO (Damage Control Officer). This person was responsible for overseeing the entire DC process, which included monitoring the automated DC systems, receiving reports from on-scene personnel (including investigators and the Casualty Coordinator), and assigning tasks to various personnel based on recommendations made by the supervisory control system, personal interpretation of events, and external orders.

5. Remote manual operation – During the FY00 demonstration, portions of the advanced damage control system operated in the remote manual mode. Remote manual DC actions were initiated verbally by the DCA. During the FY01 demonstration, fewer systems were operated in the remote manual mode. This translates to the supervisory control system causing the action to be taken. These limited remote manual actions included activation of the smoke control system and setting manual fire boundaries (where water mist was damaged or not installed).

6. Automatic operation – The advanced damage control systems that operated in automatic mode during the FY01 demonstration included the water mist system and the fire main control system. These systems were automatically operated by the supervisory control system (SCS). The SCS also included automated decision aids to facilitate SCS operations. The DCO had the ability to override these operations if necessary.

7. Tenable conditions – Based on the effects that elevated temperatures have on humans and electronic equipment, a maximum temperature of 80°C (176°F) is considered tenable. In making this determination, it was assumed that response team members would be outfitted in coveralls, flashgear, and breathing masks, such that no skin is exposed. Section 7 provides a more detailed discussion.

8. Water mist modes of operation – It is important to distinguish between the three modes of water mist operation.

   - Fire suppression (FS) mode – The SCS automatically energizes the water mist system in FS mode when fire is characterized as medium, large, or fully involved. In this mode, water mist remains on until a request is made by on-scene personnel for it to be secured or the temperature in the compartment decreases to 50°C (122°F).

   - Modified fire suppression mode – The SCS automatically switches the system to Modified FS mode when temperatures in the compartment decrease below 50°C (122°F). In this mode, water mist is pulsed on 50% of the time, off 50%. The time intervals of the water mist cycle varied, depending on the speed of the supervisory control system at the time the water mist system was being operated. If the supervisory control system was attempting to accomplish other tasks (i.e., isolating the fire main or recommending actions to the DCO), the water mist cycle may have varied.

   - Boundary cooling (BC) mode – The SCS automatically sets fire boundaries using the water mist system in BC mode when a compartment fire is characterized as large or fully involved (i.e., the water mist system is out of commission in the primary fire compartment). The SCS also energizes water mist in the adjacent compartments in BC mode if sensor data are no longer available. In this mode, water mist is activated when the temperature in the compartment reaches 60°C (140°F). At this point, water mist is energized for approximately 30% of the BC cycle. When the temperatures in the compartment fall below 60°C (140°F), water mist is secured.

9. Water mist system methods of employment – In addition to understanding the distinct water mist modes of operation (BC and FS), it is important to understand the different ways in which the system is used.

   - Activated/engaged – the water mist system is in “ready” mode. In this mode, water is not being discharged from the nozzles.
   - Energized – the water mist system is in a mode in which water is being discharged. Water is discharged when key temperature set points are reached. (Section 9 provides additional information on temperature set points).

1.2 Overview of FY98 Test Series

The first series of tests that were conducted in support of the DC-ARM program occurred in September 1998 onboard the ex-USS *Shadwell* [1], the Navy’s full-scale research, development, test, and evaluation (RDT&E) facility in Mobile, Alabama [2]. The testing involved the forward test area of the ex-*Shadwell*, which was modified to simulate the layout, accesses, and fire main features found on a DDG 51 Class ship. Test scenarios incorporated real-scale fire main ruptures in combination with various peacetime and wartime fire threats. The most severe wartime threat replicated damage associated with the detonation of a single missile hit from an antiship missile having a medium-sized warhead. Damage to the test area for the wartime missile detonation test was based on the Battle Damage Estimator model developed by Naval Surface Warfare Center (NSWC) Carderock [3].

The objectives of the FY 98 DC-ARM Demonstration were to establish a baseline evaluation to assess DC performance that can be achieved with technology currently installed aboard new-construction ships and to determine minimum manning requirements that will enable effective damage control operations. The FY98 DC-ARM demonstration served as a baseline assessment for DC manning and performance requirements. It determined that a 70-man DC organization following improved doctrine could be just as effective as today’s 105-man organization following traditional DC doctrine. Table 1 shows the breakdown of the reduced-manning organization.

Table 1 — Current vs 35% Reduced Manning Comparison

Station	Current Manning(1)	Reduced Manning	Differences
DC Central	6	3	–3
DCRS 2	36	24	–12
DCRS 3	31	24	–7
DCRS 5	32	19(2)	–13
Total	105	70(3)	–35

(1) Current manning is based on the ship manning document for a DDG 51 Class ship.
(2) With reduced manning, Repair 5 is replaced with a 13-person Rapid Response Team (RRT) and a 6-person Engineering Casualty Assistance Team (ECAT).
(3) The manning in DC Central and for Phone Talkers/Plotters in the Repair Parties is based on the use of a network of computer workstations and portable radios for maintaining and communicating DC status information.

The key paradigm shift presented in the FY98 DC reduced-manning organization was the elimination of Repair 5. (Repair 5 traditionally responded to main machinery space fires.) The rationale for deleting Repair 5 and replacing it with a Rapid Response Team (RRT) and an Engineering Casualty Assistance Team (ECAT) organization accounts for the improved capabilities available aboard modern warships. With the widespread use of diesel and gas turbine prime movers and engine enclosures aboard surface combatants, the frequency and severity of machinery space Class B fires has decreased substantially. In addition, the universal installation of Halon total flooding fire suppression systems (water mist in future ships) and aqueous film-forming foam (AFFF) bilge sprinkling has significantly reduced the risk of a catastrophic fire and the likelihood of a manned reentry under severe fire conditions.

The FY98 DC doctrine (organization and procedures) was a significant step forward in establishing the Navy's first benchmark for DC manning requirements. However, the new DC response strategy still did not adequately account for the need to respond to multiple simultaneous casualties or the need to have DC personnel continuously available to respond 24 hours a day throughout a ship's deployment.

1.3 FY98 Test Series Limitations

It was recognized that there were several weaknesses in the wartime scenario used in the FY98 test series. The test setup presented a less severe damage scenario than that predicted by the NSWC Carderock damage report [3]. This was due to physical limitations at the time of testing. To present a more realistic wartime scenario, a further review of the damage analysis was conducted. In addition to the NSWC Carderock damage report, comments received from the Naval Sea Systems Command (NAVSEA) [4] and OSD/DOT&E [5] regarding the FY98 test series were incorporated into this analysis. Also, data collected from the USS *Stark* incident [6] and weapons effect testing onboard the ex-USS *Dale* [7] were considered. It was determined that the wartime scenario would be improved by (1) extending the primary damage area to include three decks; and (2) extending the test area horizontally so that containment by DC personnel could be demonstrated and evaluated. Extension of the primary blast area to include Auxiliary Machinery Room (AMR) No. 1 more closely simulated the predicted damage and posed a realistic threat for evaluating the proposed DC reduced manning organization. Extending the test area horizontally allowed a more thorough evaluation of critical DC operations (containment, boundary maintenance, and manning allocation) and the effectiveness of advanced systems. Based on this analysis, the test area was modified to simulate a more challenging and realistic wartime scenario.

1.4 Overview of FY00 Test Series

The second set of demonstrations was conducted in September 2000 [8]. In comparison to the FY98 tests, the focus of these tests was not on manning. Rather, the focus was to evaluate new systems and technologies to assist with the goal of reducing the size of the DC manning organization. These demonstrations used remote manual operation of advanced systems (e.g., water mist suppression system, fire main control system, and smoke control system) used for intervention during DC casualties. The demonstrations also incorporated the use of early-warning fire detection (EWFD), shipwide video, and door-closure sensor systems. The DC-ARM Supervisory Control System was introduced and exercised during these demonstrations. The SCS provided the DCA with automated situation awareness about the casualty. In addition, it provided remote manual control of the water mist, fire main, and smoke control systems.

The demonstrations again included peacetime and wartime scenarios. Peacetime scenarios consisted of small, but growing, fires and nuisance sources. The intent of the peacetime scenarios was to demonstrate

improved situation awareness through the use of the SCS, shipwide video, and early-warning fire detection systems.

The wartime scenario demonstrations were performed to show improved situation awareness and containment of damage to the PDA. Modified measures of performance from the FY98 test series evaluated the effectiveness of the DC-ARM systems. The wartime tests incorporated the modified damage prediction expected from the detonation of a medium-sized warhead. Damage to the ship structure and ship systems was included. This damage included ruptures to the fire main, loss of sensors (including video), and inoperable sections of the water mist system.

While the focus of the FY00 demonstration was not on manning, some nontraditional manning concepts were incorporated into the demonstrations. For both peacetime and wartime scenario demonstrations, the DCA was responsible for supervising casualty operations. He was assisted by the DC Watch Supervisor, the Plotter/DC System Operator, and the Video Coordinator. The DC Watch Supervisor was responsible for monitoring the SCS and responding to decision aids at the discretion of the DCA (such as activation of water mist). The Plotter/DC System Operator plotted status reports that were received in Damage Control Central (DCC) and operated the fire main control system. As requested by the DCA, the Video Coordinator received additional status information by monitoring cameras throughout the forward portion of the ship.

For peacetime demonstrations, a modified Rapid Response Team was used. Rather than using the 13-man RRT organization used in FY98, an 8-man RRT was developed. This team consisted of an On-Scene Leader, 2 Primary Responders, 2 Investigators, and a 3-man Attack Team. The DC manning organization for wartime demonstrations included an 8-man RRT and a 9-man Back-up Repair Team organization. The RRT served as a Battle Damage Assessment Team (BDAT) during the wartime tests. The Back-up Repair Team consisted of an Attack Team (4 people), a Support Team (4 people), and a Casualty Coordinator.

The primary focus for the FY00 DC-ARM wartime demonstration was to validate that the DC-ARM systems could limit damage to the PDA. With the assistance of the SCS, the DC organization was expected to contain the fire(s), isolate fire main ruptures, and maintain tenable conditions (i.e., good visibility and temperature conditions) around the PDA. Indirect fire attacks were initiated once these goals were achieved.

1.5 FY00 Test Series Limitations

As discussed in Section 1.4, the focus of the FY00 test series was limited to evaluation of the automated systems and technologies developed to assist with reducing the size of the DC manning organization. As such, the manning organization was not fully tested or evaluated.

2. OBJECTIVES

The objectives of the FY 01 DC-ARM Demonstration were to demonstrate the integrated use of automated DC systems; quantify the benefits and limitations associated with the use of these systems; review alternative DC organizations; and develop appropriate doctrine for the reduced manning organization.

To interface directly with the DC-ARM SCS, the advanced damage control systems incorporated the EWFD system, the water mist fire suppression system, the fire main control system, the shipwide video system, and the door-closure system. The SCS provided the DCO with overall situation awareness, and automatic control of the water mist, fire main, and video systems. The ventilation systems were not automated; rather, the smoke control system was activated by the DCO via a console switch located in DCC.

The FY01 demonstrations included peacetime and wartime scenarios. The peacetime demonstrations were performed to validate the RRT concept and demonstrate improved situation awareness. The wartime demonstrations were performed to show improved situation awareness and to challenge the reduced DC manning organization. The capability of the DC organization was evaluated using measures of performance modified from the FY00 test series [8].

3. APPROACH

3.1 General Approach

The FY01 demonstrations were again conducted in the Forward Surface Ship test area of the ex-*Shadwell*. The scenarios consisted of peacetime and wartime conditions. Peacetime scenarios included flaming, smoldering, and nuisance sources. Wartime scenarios provided fast-growing fires ignited from a simulated single hit by a missile with a medium-sized warhead.

The peacetime scenarios were intended to validate the RRT concept and demonstrate improved situation awareness through the use of the SCS and EWFD systems. For the peacetime tests, EWFDs and commercial off-the-shelf (COTS) detectors were installed throughout the test area. Digital video images were provided to the SCS Surveillance Video presentation via the ex-*Shadwell* local area network (LAN).

The wartime tests incorporated the damage expected from the detonation of a medium-sized warhead. Damage to the ship structure and ship systems included ruptures to the fire main, loss of sensors (ex-*Shadwell*, door closure, COTS, and video), and inoperable sections of the water mist system.

During the wartime tests, the primary focus was to ensure that the damage was contained and that fire did not spread uncontrollably to APDA compartments. With the assistance of the SCS, the DC organization was expected to contain the fire(s), isolate fire main ruptures, and maintain tenable conditions (i.e., good visibility and temperature conditions) around the PDA. Indirect fire attacks were permitted once these goals were achieved. Direct fire attacks were also permitted at the discretion of the DCO.

3.2 Damage Control Organization

The reduced manning doctrine study considered a variety of DC manning concepts and lessons learned from previous DC-ARM demonstrations. These DC manning concepts included:

- The conventional at-sea fire party and general quarters organization currently used by the Surface Fleet,
- The Core/ Flex approach pioneered by the Smart Ship and further refined by DESRON EIGHTEEN,
- Submarine Casualty Response Parties exercised aboard the ex-USS *Shadwell*, and
- Lessons learned from past Fleet Doctrine Evaluation (FDE) tests aboard the ex-*Shadwell*.

The study discovered early on that any new DC manning concept must properly integrate the use of DC-ARM-like system technologies, and promote a *continuous* response and *orderly transition* process to changing operational readiness conditions. It was noted that previous reduced DC manning initiatives did not properly account for the requirement to respond to multiple simultaneous casualties or the need to respond continuously, 24 hours a day.

Figure 1 shows the developed DC-ARM 45-man DC organization and response strategy. The new DC organization adopts the USS *Lake Erie* (CG 70) Blue/Gold process [9], and provides for

- a 6-man RRT augmented with an 11-man back-up response organization for Condition III/ IV cruising; and
- a forward and aft casualty repair organization, including a BDAT to facilitate weapons-induced damage investigation during Condition I.

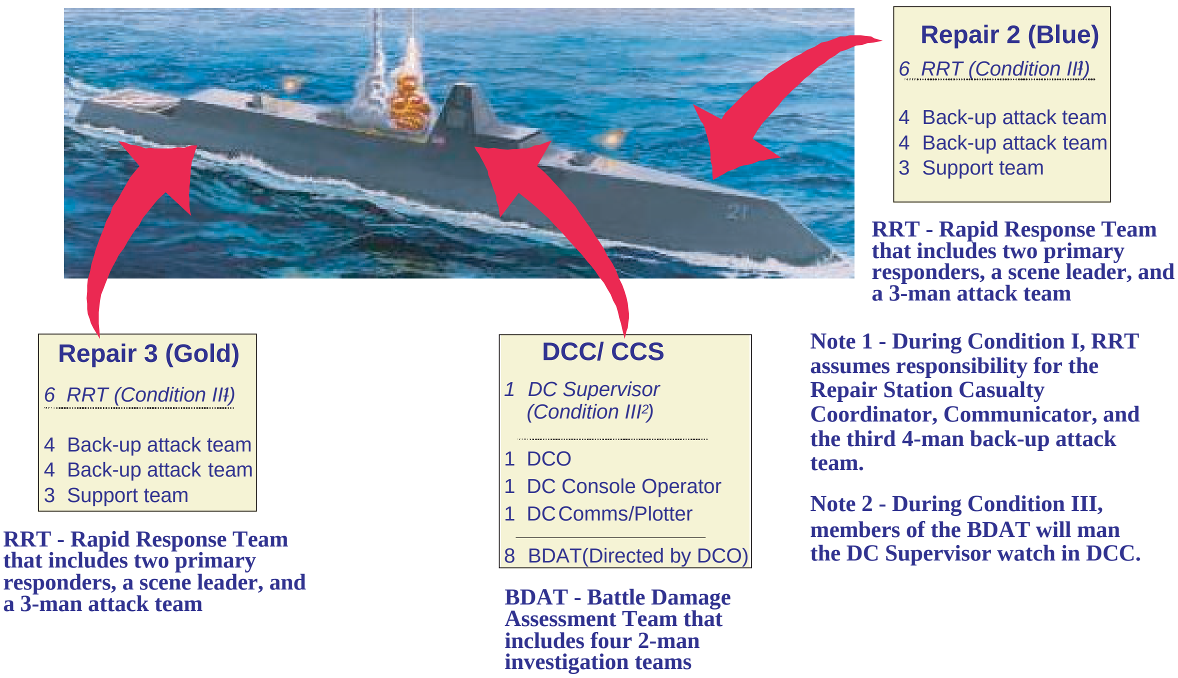


Fig. 1 — DC-ARM 45-man DC organization and response strategy

For an optimally manned ship, it is assumed that general maintenance and upkeep duties will be apportioned to some percentage of the crew complement. For this demonstration, it was presumed that this portion of the crew could also serve as the ship's primary damage control organization. Therefore, under the Blue/ Gold process, this Maintenance/DC group would be divided into two equal repair teams and also account for the designated Condition III and I watch requirements for DCC.

When using this response strategy, the on-duty RRT would be responsible for responding to any damage control emergency happening aboard the ship during Condition III/IV. If the casualty was deemed beyond their capability or a heightened threat level was instituted, the corresponding back-up repair (Blue or Gold) organization would be stationed to assist, as necessary. If the threat level continued to increase or the threat approached a specified battle order condition, the ship would then go to general quarters and both Repair (Blue/ Gold) organizations and the BDAT would report to their designated Condition I battle stations.

During the DC-ARM live fire exercises, the make-up and size of the DC response and damage assessment teams were adjusted as the challenge of the test scenarios changed to both identify the minimum manning required and uncover any weakness in the organization. In addition, some personnel or functions were eliminated to further identify the essential/nonessential positions and functions.

Only one half of the DC organization (i.e., Repair party (17 persons), the BDAT (4 persons) organization, and DCC (3 persons)) was exercised during the FY01 DC-ARM demonstration. This was done to validate and demonstrate that the determined reduced-manning DC organization, augmented with DC-ARM-like technologies, could handle two major flooding and fire incidents concurrently as would be expected with today's fully manned DC organization onboard a DDG 51 Class ship.

4. TEST SETUP

4.1 General Description

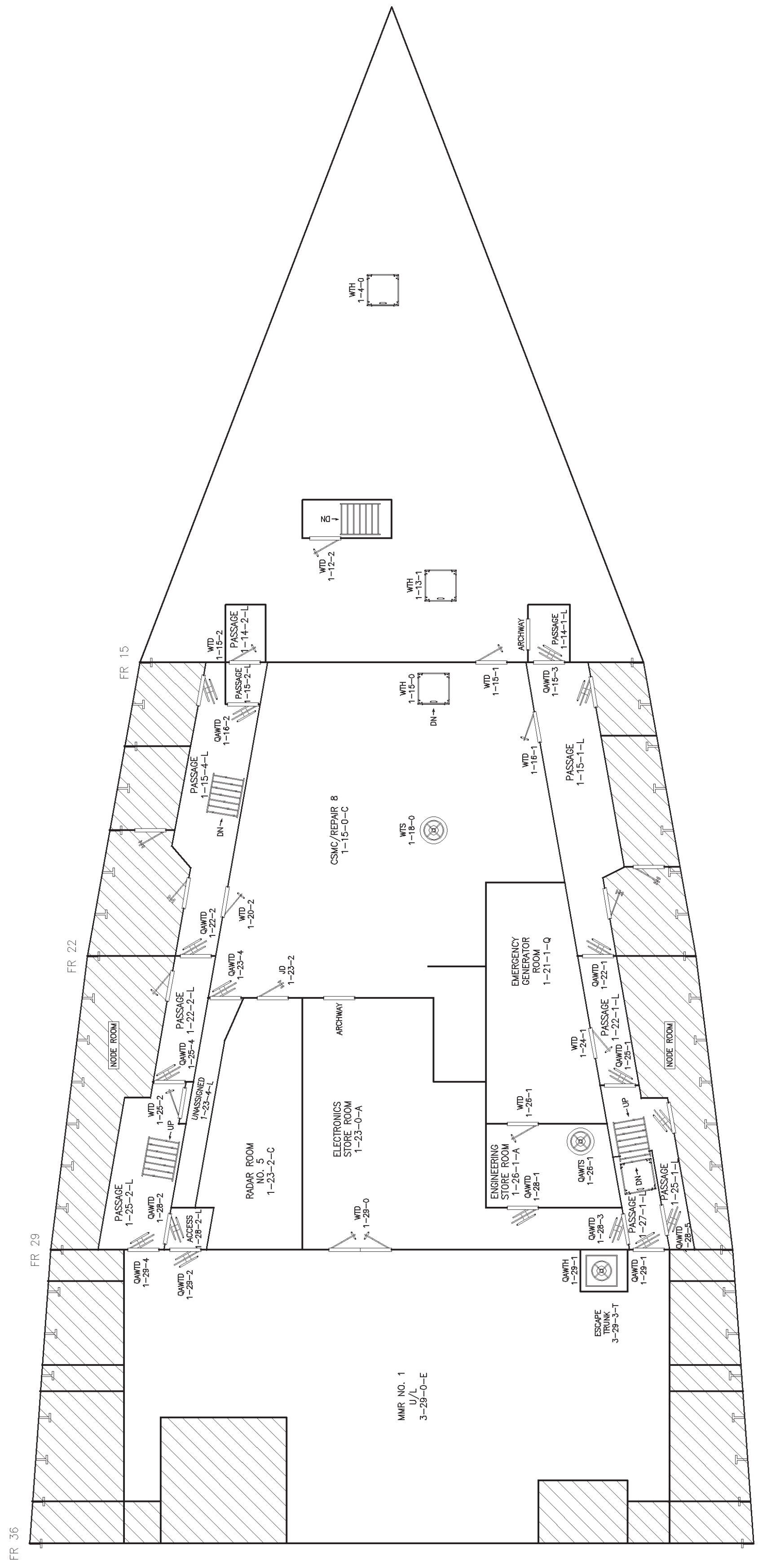
The test area consisted primarily of FR 9 to FR 29 on the main through fifth decks (i.e., hold level). The test space was configured to simulate the DDG 51 platform as closely as possible, given the ex-*Shadwell* geometry and the resources available. Table 2 compares the primary test compartment locations on DDG 51 Class ships and the ex-*Shadwell*. Figures 2 through 6 provide an overview of the test area and compartment designations. Compartments not included in the test area have been hatched.

Some of the accesses in the test area were restricted for use by Safety Team personnel only. Appendix A is a set of drawings locating the Safety Team accesses.

Blast panels were installed in the second and third decks (Figs. 7 and 8). These panels were removed during wartime tests to simulate the damage that may occur from a warhead detonation. The openings provided free communication between the Comm Center and CIC, and the Comm Center and AMR No. 1. Cabinets, bunks, and office furnishings were placed in compartments adjacent to the PDA to create a more realistic environment in which the test participants had to navigate. In addition, fuel packages used for sympathetic ignition in APDA compartments were also placed in these spaces.

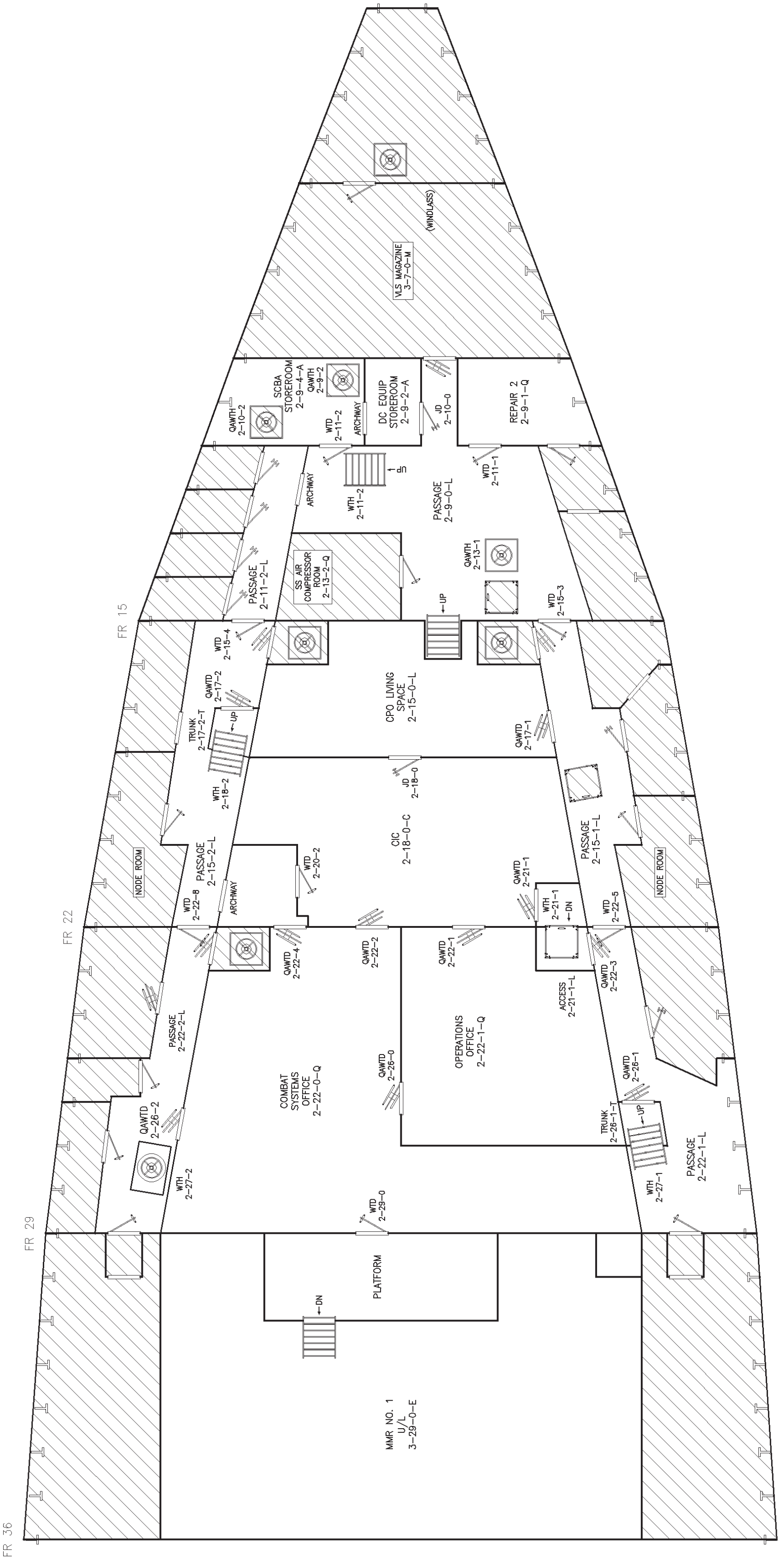
Table 2 — Space Designations for DDG 51 Class Ship and ex-USS *Shadwell*

Space Designation	DDG 51 Location	*Shadwell* Location
CSMC/Repair 8	01 Level	Main Deck (FR 15 - FR 23)
CPO Living Space	Main Deck	2nd Deck (FR 15 -FR 18)
CIC	Main Deck	2nd Deck (FR 18 - FR 22)
Operations Office	Main Deck	2nd Deck (FR 22 - FR 27, starboard side)
Combat System Office	Main Deck	2nd Deck (FR 22 - FR 29, port side)
Crew Living	1st Platform	3rd Deck (FR 15 - FR 18)
Comm Center	1st Platform	3rd Deck (FR 18 - FR 22, with dog-leg on port side to FR 24)
Radio Transmitter Room	1st Platform	3rd Deck (FR 22 - FR 24, starboard side)
Tomahawk Equipment Room	1st Platform	3rd Deck (FR 24 - FR 27, port side)
Engineering Storeroom	1st Platform	3rd Deck (FR 24 - FR 29, starboard side)
AMR No. 1	2nd Platform/Hold Level	4th Deck/Hold Level (FR 22 - FY 29)
MMR No. 1	2nd Platform/Hold Level	4th Deck/Hold Level (FR 29 - FR 36)



NOTE:
HATCHED AREAS ARE NOT PART OF TEST AREA.

Fig. 2 — Layout of Main Deck



NOTE:
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Fig. 3 — Layout of Second Deck

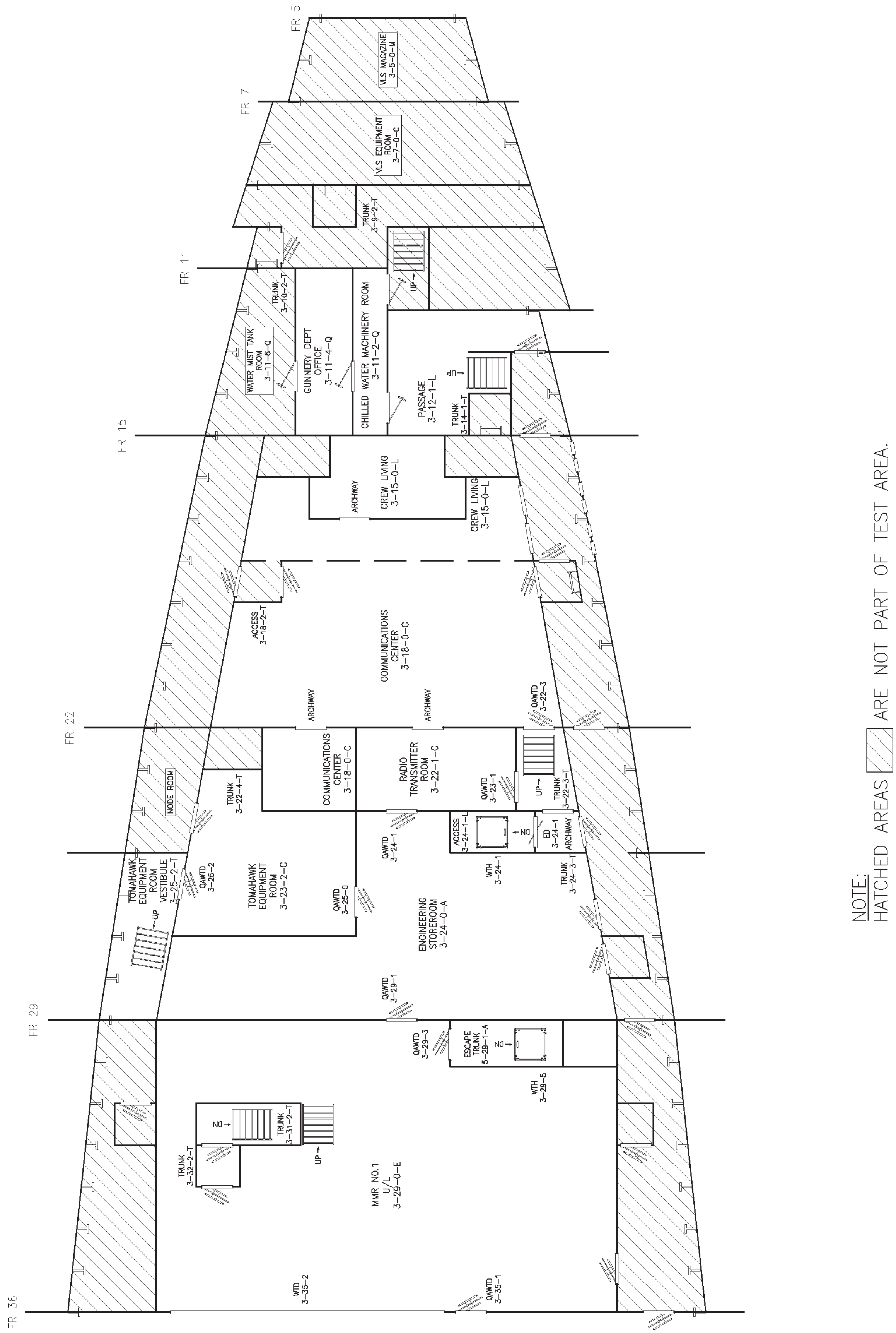
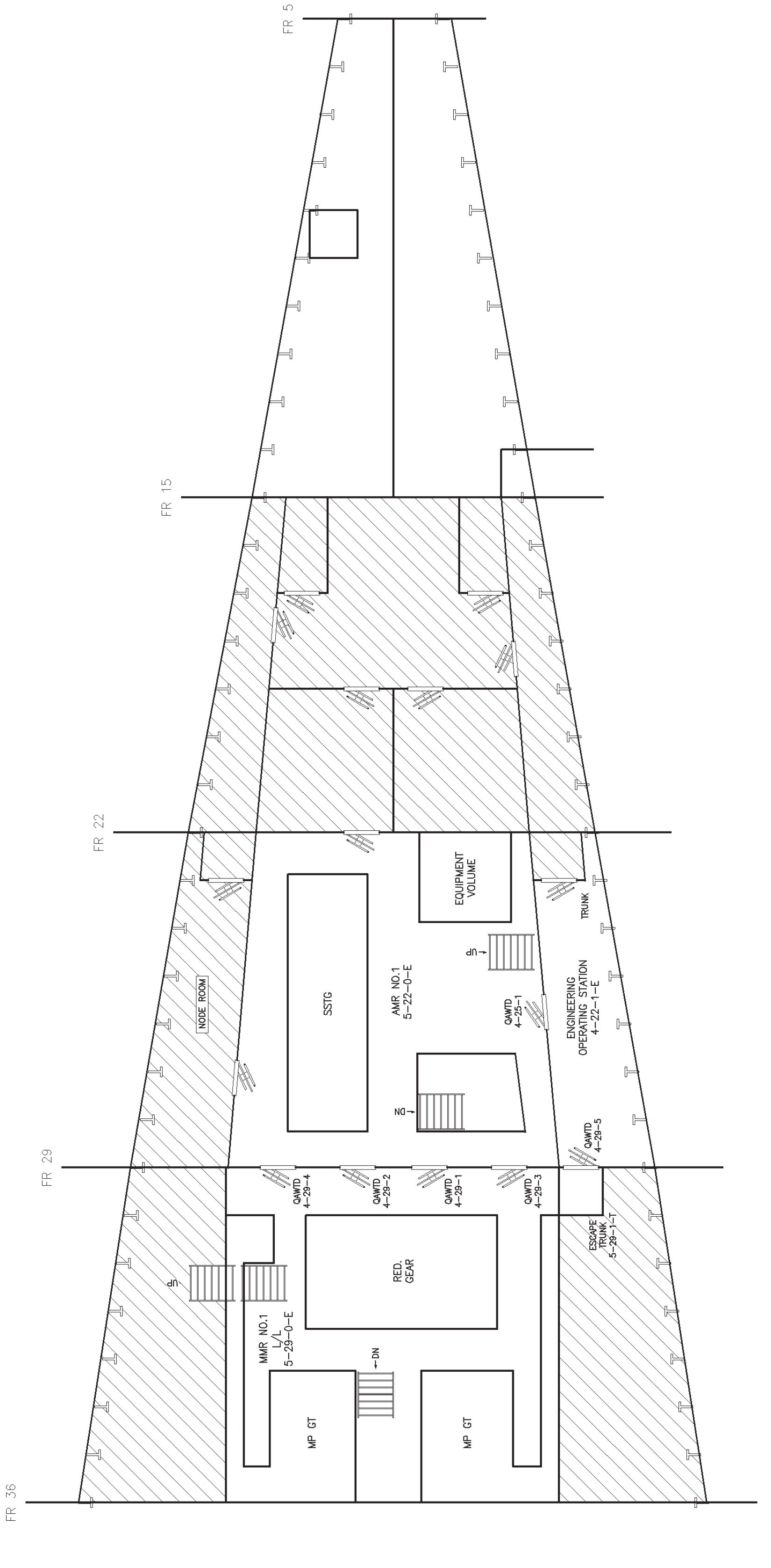


Fig. 4 — Layout of Third Deck



NOTE:
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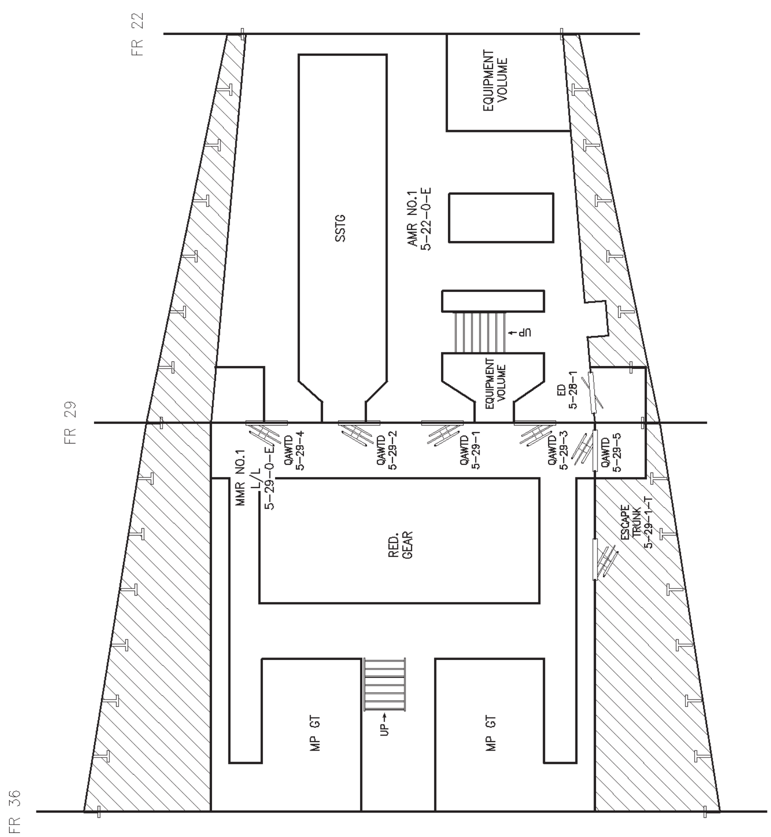
Fig. 5 — Layout of Fourth Deck



NOTE:
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Fig. 6 — Layout of Hold Level

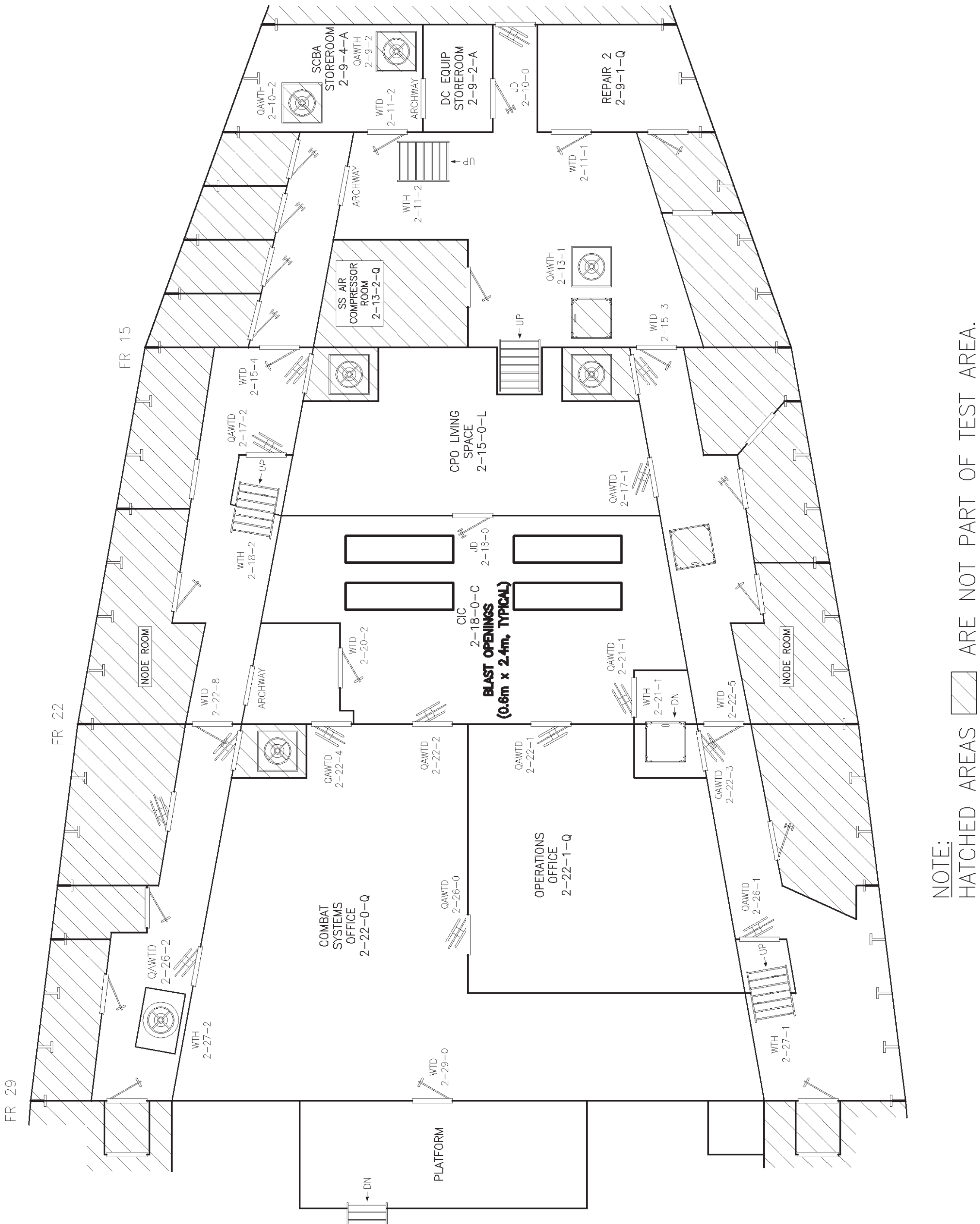


Fig. 7 — Blast openings in the Second Deck

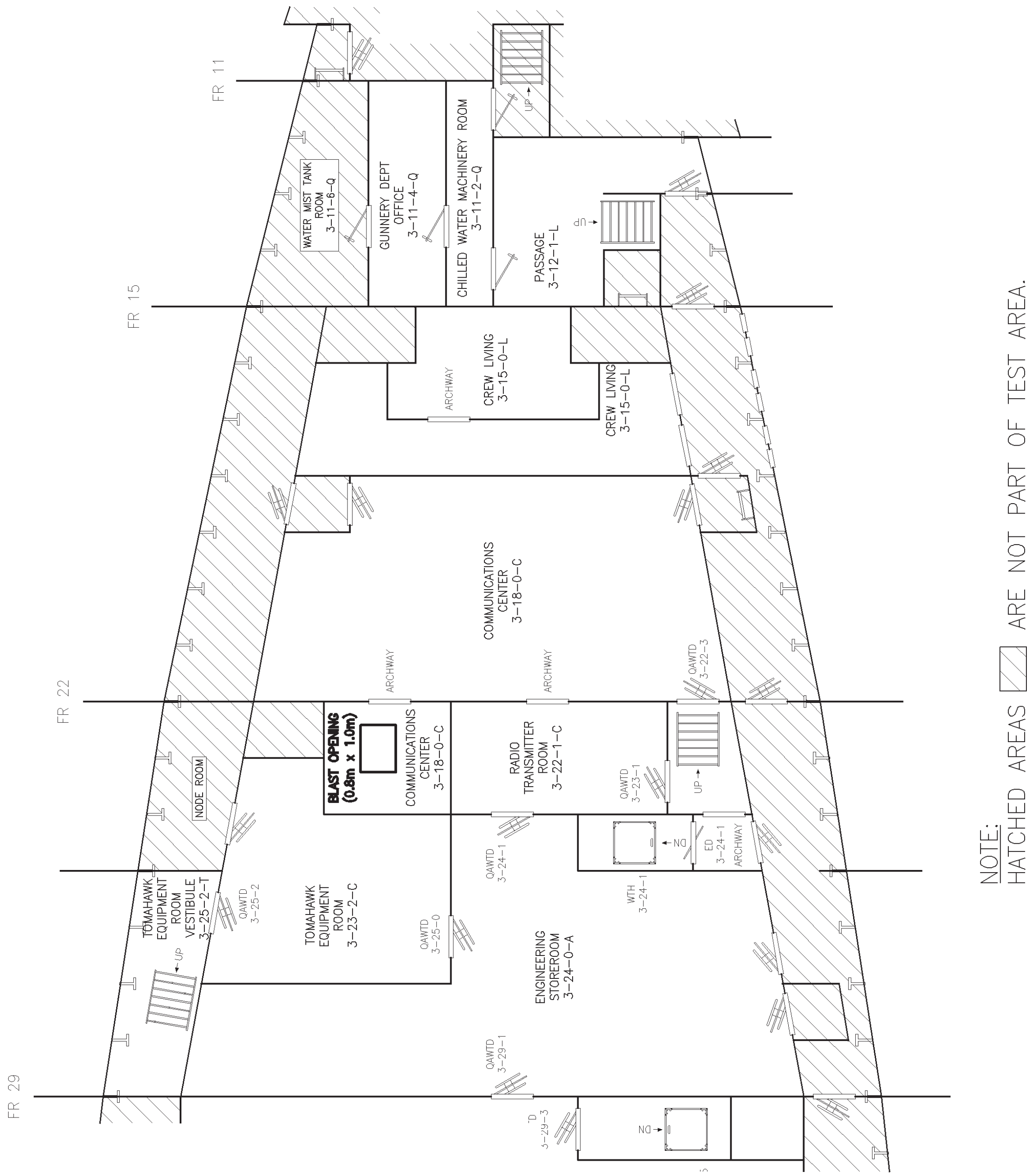


Fig. 8 — Blast openings in the Third Deck

For the FY01 demonstration, DCC was located on the port side of the 01 Level, between FR 46 and FR 50 (Fig. 9). An SCS workstation and display screens were positioned on one cabinet that was manned by the DC Watch Supervisor. A separate display/workstation consisting of three large projection screens was provided for use by the DCO. The DC Comm Operator/Plotter used the computer-operated plotting system, which provided human-generated reports input to the SCS. Section 4.13 provides a more complete description of the supervisory control system.

Fig. 9 — DC Central with Intelligent Supervisory Control System

The Test Director oversaw the entire test series in the ex-*Shadwell* Control Room, located on the 02 Level. Personnel in the Control Room monitored test data and video of the test spaces. The test team assured that the tests were conducted safely and implemented various casualty events independent of the DCO and other test participants. Variations in test scenarios provided a means to assess how the DC-ARM systems and the test participants responded to the damage control events.

4.2 Test Area Modifications

With the exception of one modification, the test area had the same configuration as that used during the FY00 demonstration. For convenience, Trunk 3-13-1-T was replaced with an inclined ladder. Additionally, the location of DCC was different than during the FY00 demonstration; at that time, it was located in the ex-*Shadwell* Control Room. As discussed in Section 4.1, a new compartment was constructed on the port side of the 01 Level between FR 46 and FR 50 (aft portion of the Crew Mess).

4.3 Fire-Fighting Equipment

Figures 10 through 14 show the locations of fire main-related fire-fighting equipment and portable extinguishers. Fire main-related fire-fighting (or boundary cooling) equipment included fireplugs, two

19-cm (0.75-in.) fresh water hose reels, and two 3.8-cm (1.5-in.) AFFF hose reels. Fireplugs (3.8-cm (1.5-in.) sea water) were installed such that every part of the test area could be serviced by two fireplugs using no more than 30 m (100 ft) of fire hose from each plug (Figs. 10 and 11). The fireplugs were located near vertical accesses so that progressive fire fighting starting from the DC deck was easily facilitated. Two 1.9-cm (0.75-in.) fresh water hose reels were located near the port and starboard entrances to CIC. Figure 11 shows these locations. A 3.8-cm (1.5-in.) AFFF hose reel was positioned outside the starboard side entrance to the Comm Center on the third deck for use in fire fighting activities in AMR No. 1. A second 3.8-cm (1.5-in.) AFFF hose reel was located outside the hold level entrance to the escape trunk, between FR 27 and FR 28, for use in fire fighting activities in AMR No. 1. Figures 12 and 14 show the locations of the two AFFF hose reels.

Portable fire extinguishers included CO_2, PKP, and AFFF extinguishers. Carbon dioxide and PKP extinguishers were placed in locations similar to those found on DDG 51 Class ships. AFFF extinguishers were also placed in some of these locations to enhance the capability to fight Class A fires. Figures 10 through 14 show the locations of the fire extinguishers.

In addition, essential damage control equipment was distributed throughout the test area. This DC equipment was comparable to that which would be available to DC personnel on DDG 51 Class ships. This equipment included an exothermic torch, portable eductors, smoke control equipment and hull repair/ plugging kits. Personal protective equipment such as SCBAs, fire fighting ensembles (FFEs), helmets, fire fighting boots, gloves, and antiflash hoods were also prepositioned throughout the damage control repair station [10-12].

4.4 Fire Main Control System

As part of the FY98 test program, a fire main having a configuration similar to that of the associated area on a DDG 51 Class ship was installed in the test area. This fire main included two offset mains on the port and starboard sides of the main and second decks. Cross connects were located at FR 12 and FR 23. Two fire pumps (Fire Pump 1 and Fire Pump 2) were used to supply the main. Appendix B provides schematics of the fire main system. The fire main was outfitted with 17 isolation valves. Eight of these valves were provided with reflexive capability (i.e., Smart Valves), and the remaining nine valves were remote manual valves. The fire pumps and fire main isolation valves were arranged so that the fire main could be operated in any standard configuration (XRAY, YOKE, or ZEBRA) [13]. A LonWorks network was used to control the fire main. LonWorks nodes were installed for instrumentation, valve controls, and pump controls.

The Smart Valves were instrumented with imbedded pressure sensors that provided data for identifying fire main ruptures. Two algorithms for rupture isolation have been developed [14-15]. Using a hydraulic resistance logic approach, the system can function in the reflexive mode. In this mode, the processor at each valve will identify whether a rupture condition exists and open or close automatically. These processors base decisions on local data. In the nonreflexive mode, local data are assembled and interpreted using a flow balance algorithm at the central processor (i.e., the SCS fire main control function), providing analysis at a high level. The nonreflexive mode provides a faster time for rupture detection and isolation. For the FY01 demonstrations, the fire main control system was operated in the nonreflexive mode.

Three rupture locations were installed in the fire main to simulate damage to the mains. These locations included the Operations Office, Port Passageway (Main Deck), and the Starboard Passageway (2nd Deck). All ruptures were opened (as compared to being piped to a tank) so that flooding would occur if the rupture was not quickly isolated.

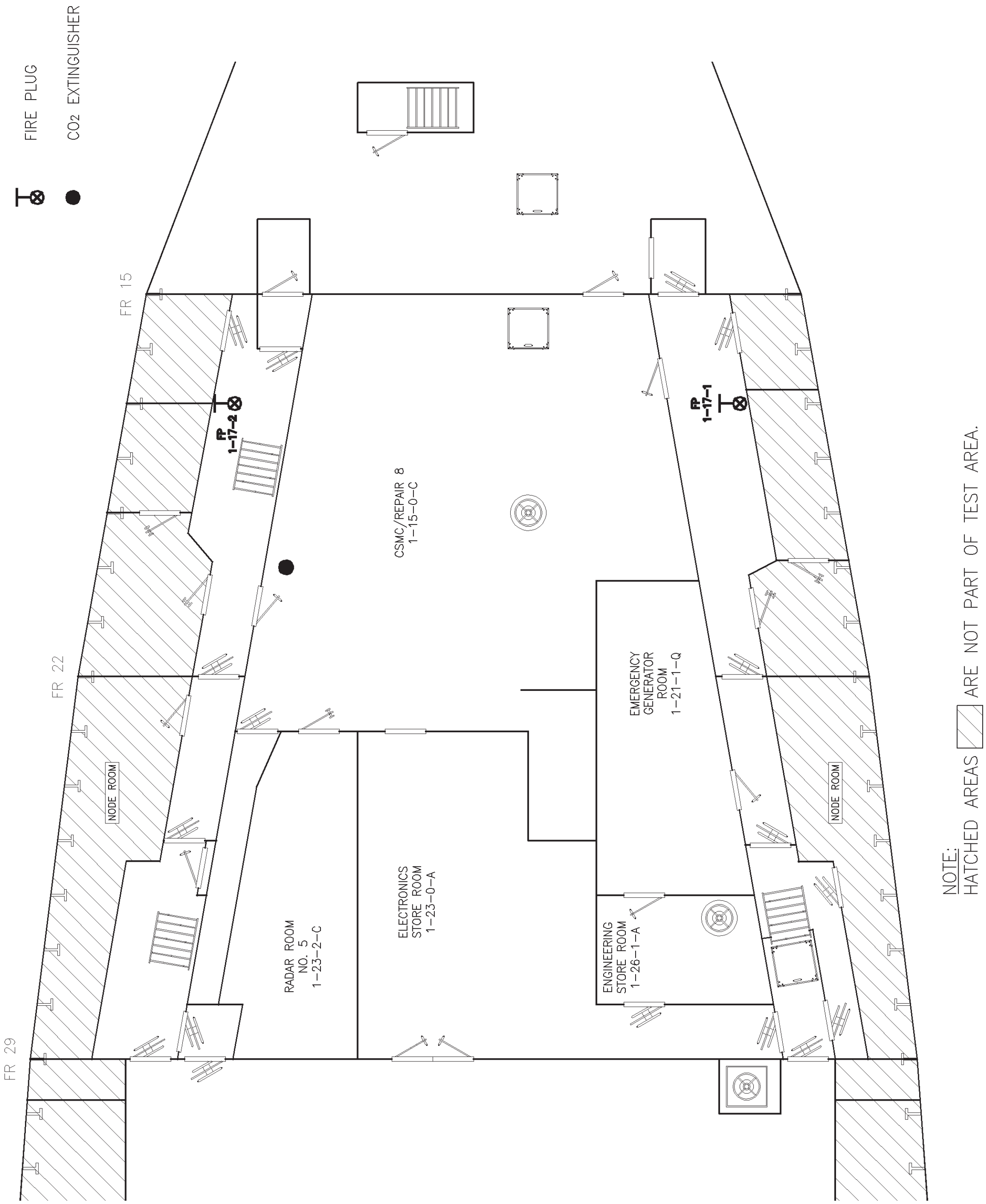


Fig. 10 — Location of DC Equipment on the Main Deck

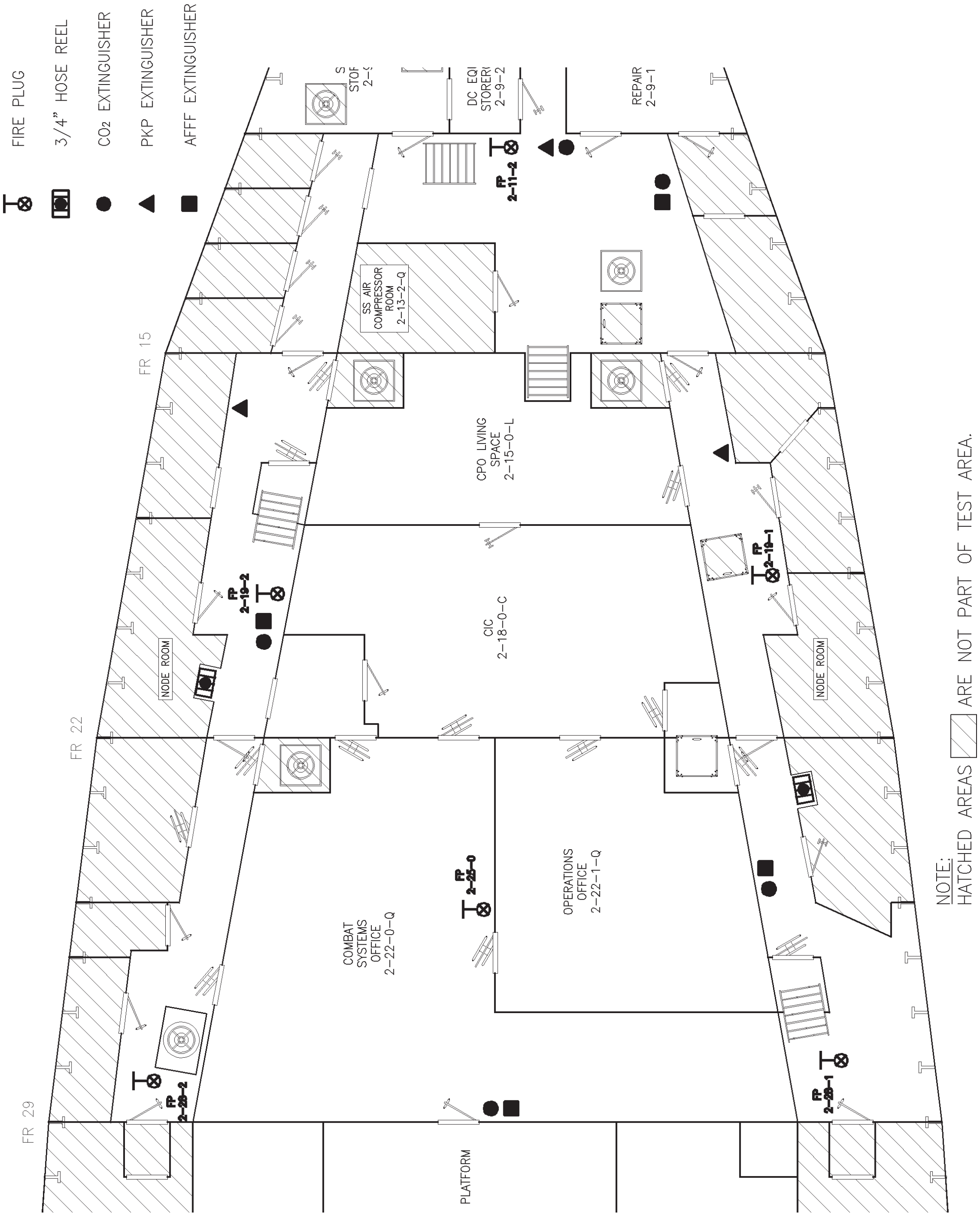


Fig. 11 — Location of DC Equipment on the Second Deck

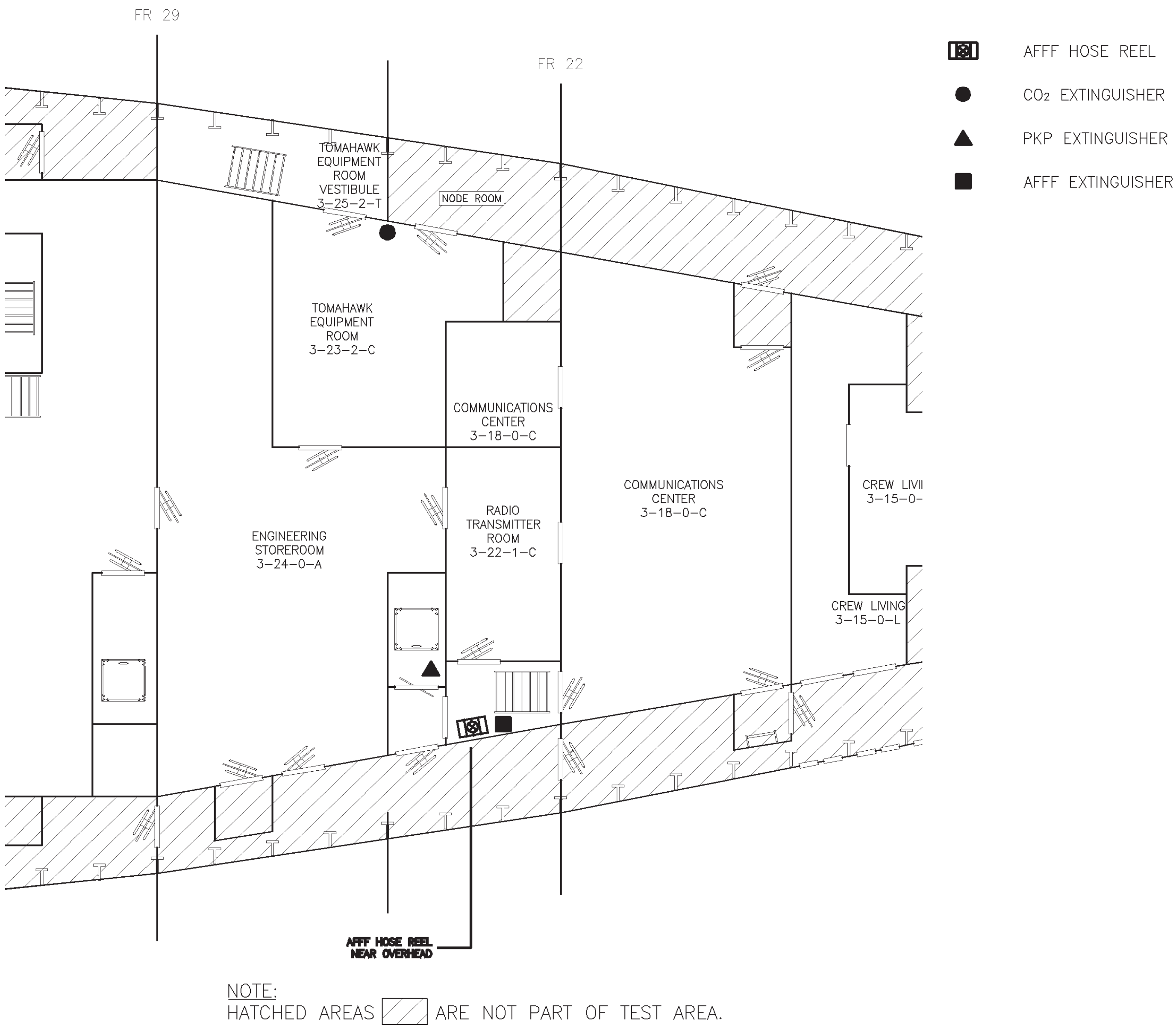


Fig. 12 — Location of DC Equipment on the Third Deck

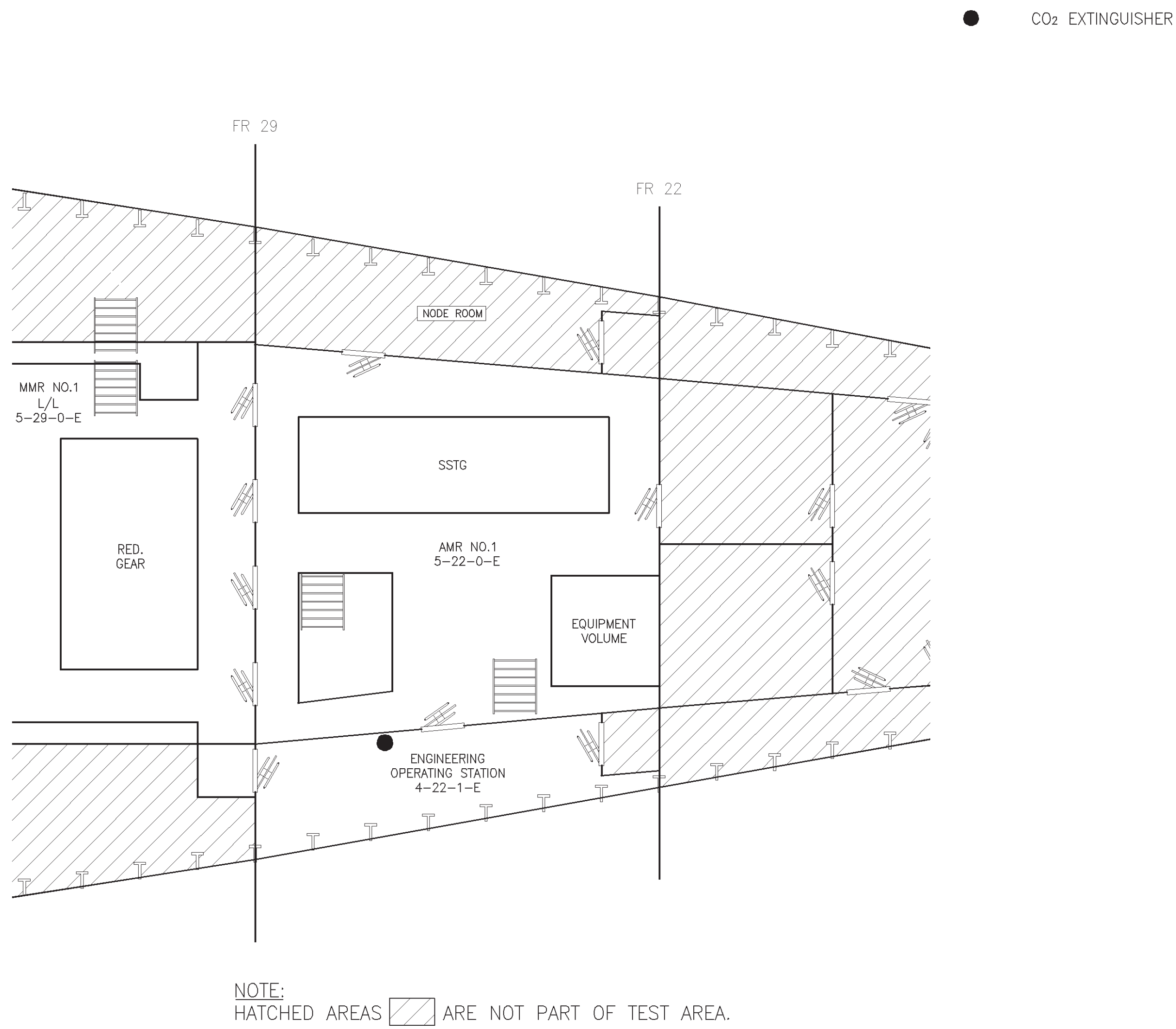


Fig. 13 — Location of DC Equipment on the Fourth Deck

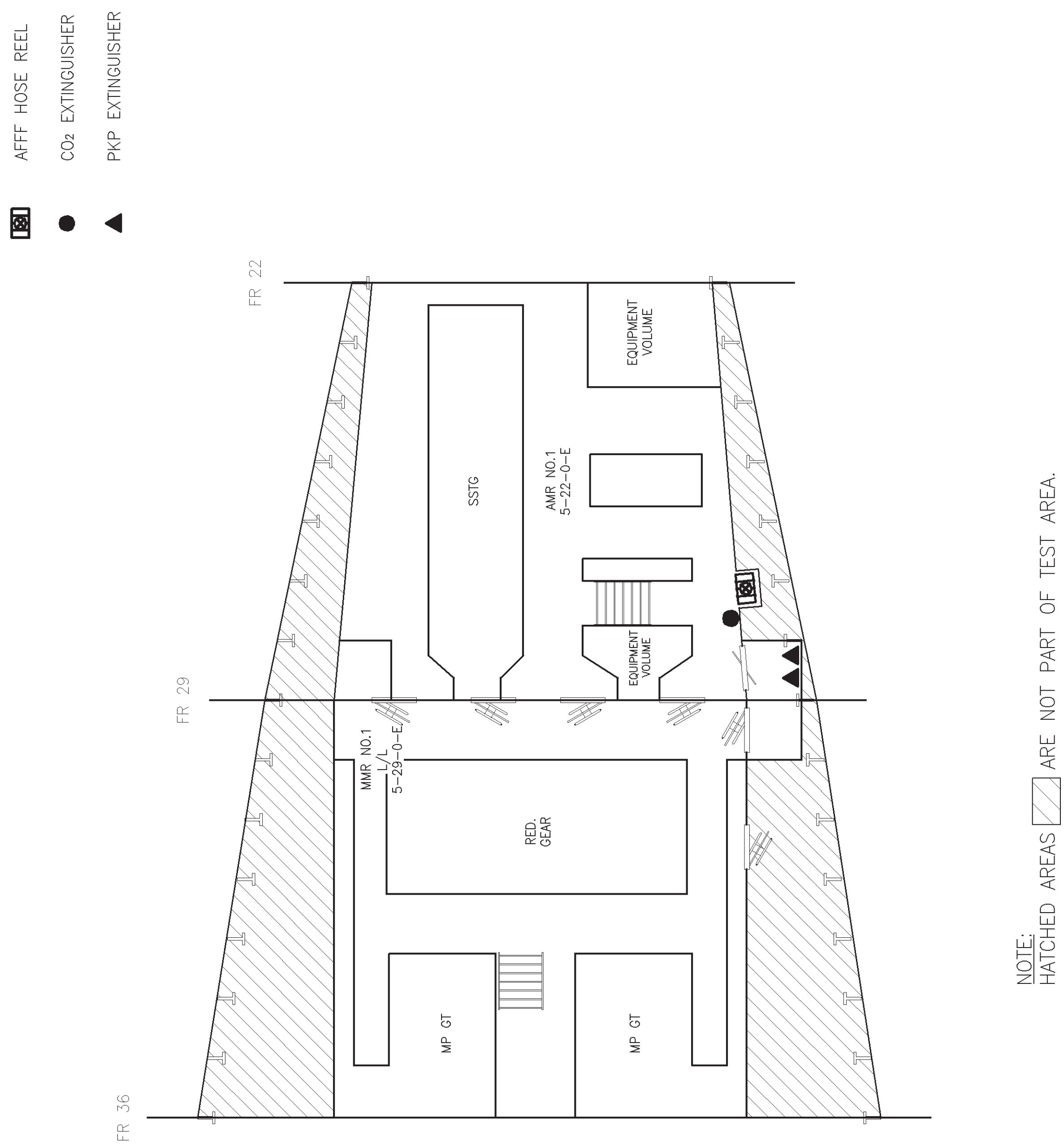


Fig. 14 — Location of DC Equipment on the Hold Level

4.5 Water Mist Suppression System

A high-pressure (68 bar (1000 psi)) water mist suppression system was installed for use during the FY01 demonstration. This system was installed in compartments within the test area on the main, second, and third deck to provide an area-wide fire protection system. The water mist system was controlled and operated through the SCS water mist control function.

The water mist system serving the test area was constructed using the sectional loop architecture described in Ref. 16. This design was tailored for rupture isolation; however, rupture isolation was not incorporated into the FY01 demonstration. Rather, the system was assumed inoperable in PDA compartments for wartime scenarios and the piping was physically isolated.

A new pumping system (consisting of multiple pumps) was installed on the fourth deck at FR 16. This system was designated the Forward Pumping Unit. It has the ability to adjust continuously to meet a range of flow demands. The forward pumping unit supplied water to the mains that in turn fed branch group nozzles. The nozzles used were open (deluge) type. Appendix C provides schematics for the piping network and nozzle layout.

An electrically actuated solenoid valve controlled each branch group of nozzles. These valves are referred to as water mist control valves (WMCV). Wiring from each WMCV was connected to one of two node rooms located in the second deck test area.

Water mist cutout valves (WMCO) were also incorporated into the system design to provide rupture isolation. Since isolation of ruptures in the water mist system was not included as part of the FY01 demonstration, these valves were not operated during this test series.

4.6 Ventilation

The ship ventilation system was operated in two modes: Collective Protection System (CPS) and SES. The DCO had the ability to control the ship ventilation systems within the test area from DCC. Combustion air for the missile hit flashover fires was enhanced independently through the use of the direct current fans (E 1-15-1 and E 1-15-2) from the ex-USS *Shadwell* Control Room.

4.6.1 CPS Mode

The CPS onboard the ex-USS *Shadwell* was used for "normal" ventilation during these demonstrations. The CPS ventilation system has been installed on DDG 51 Class ships to provide an overpressure of 0.5 kPa (2 in.) of water for a given pressure zone. The purpose of this overpressure is to provide protection from chemical, biological, and radiological (CBR) hazards. CPS supply and exhaust terminals are distributed throughout the test area on the ex-USS *Shadwell* [17-18]. Three supply fans (TPSS (Total Protection Supply System) 1-31-1, 1-31-2, and 01-25-2) and three exhaust fans (TPES (Total Protection Exhaust System) 1-16-1, 1-16-2, and 1-16-4) were used to provide ventilation. Each fan had two settings, on and off, that were controlled manually from a toggle switch in DC Central. Unless the DCO directed otherwise, CPS ventilation was on during each demonstration.

4.6.2 SES Mode

The design for the LPD-17 SES was used for desmoking during the FY01 demonstrations. This system was mocked up and evaluated on the ex-USS *Shadwell* in 1998 [19-21]. The purpose of the system is to

remove smoke from DC deck (second deck) passageways and to prevent smoke from entering Combat System Maintenance Central (CSMC)/Repair 8. SES terminals located in the second deck passageways provided a high air exchange rate within the passageways to purge smoke. SES terminals located in the main deck passageways were balanced such that the passageways were at a pressure slightly less than that in CSMC/Repair 8, thus preventing smoke infiltration into that compartment. Appendix D provides the locations for these terminals.

Ventilation was provided to the SES terminals using the CPS fans. When operating in SES mode, air was diverted from CPS terminals to SES terminals. As a result, the CPS fans could operate in either CPS mode or SES mode. This selection was manually controlled from a toggle switch in DCC, which was made available to the DCO.

Data collected during tests on ex-*Shadwell* showed that this system is capable of restoring visibility to 6.1 m (20 ft) in DC deck passageways in 0.5 to 5 minutes [20, 21]; initial visibility conditions were less than 1.5 m (5 ft). This range in performance corresponds to different air exchange rates that were tested. This system was not designed to remove smoke from compartments adjacent to the protected passageways. As a result, the system was not used for desmoking internal compartments during these demonstrations.

4.7 *Shadwell* LAN

The *Shadwell* LAN consists of three subnets that are interconnected. These subnets include the blown fiber network, the SHADWELL_NT network, and the DCS network. The blown fiber network is a gigabit Ethernet system. It is installed in the Control Room and nine node rooms throughout the ship. The SHADWELL_NT subnet is a thinnet, 10 Base-2 (RG-58 coaxial cable) LAN. This subnet supports the Control Room and adjacent areas. The DCS subnet is a fiber-optic Passive-Star LAN. During this test series, the DCS subnet supported the SCS Remote Terminal in Repair 2. Reference 22 provides a more detailed description of the *Shadwell* LAN.

Users are connected to the *Shadwell* LAN through one of the subnets. During the FY01 Demonstration, this network allowed the supervisory control system to communicate with the DC sensor systems in real-time. The DC sensors systems included the Shadwell sensors, the EWFD system, and door-closure sensors. Additionally, the SCS water mist control and surveillance video functions were also distributed over the *Shadwell* LAN.

4.8 *Shadwell* Sensors

Instrumentation was installed in various test compartments to measure temperature, smoke density (visibility), heat flux, gas concentrations, and air pressures. Pressure transducers and flow meters were also used to measure fire main pressure and fire plug water flow rates. These data were collected on the MassComp, the *Shadwell* data acquisition computer, and were made available in real-time over the *Shadwell* LAN. The supervisory control system used these data to provide automated situation awareness for the DCO. Appendix E provides detailed sensor location drawings.

To simulate the damage that may occur as a result of a missile hit, some of these sensors were "damaged" during the wartime demonstrations. This damage was simulated in three different ways. The first means of simulating faulty data was to replace data for sensors typically located in the PDA with a default value of –5000, to represent a sensor that was permanently destroyed or the wire was severed. This value

was used because it is the default value of the data acquisition system for an open channel. All sensors in the PDA were assumed destroyed and thus had the first type of damage. The second type of faulty data was simulated by imposing a random noise of –50% to +50% to the actual sensor data. The third type of faulty data represented sensors with shorts or intermittent connections. This was simulated by imposing a random multiplier of –50 to +50 to the sensor value. Either the second or third means of simulating faulty data were used in various APDA compartments. Typically, faulty data were initiated immediately after the missile hit. Although the SCS was not able to access the actual data from the "damaged" instrumentation, the true (i.e., undamaged) values were recorded in the Control Room for use in analyzing the test results. Appendix F provides details on the damaged channels used during each of the wartime demonstrations.

4.8.1 Thermocouples

Thermocouples were placed within the test area to measure air, bulkhead, flame, deck and overhead deck temperatures. Air thermocouples were located either approximately 0.2 m (0.5 ft) below the overhead (high), or 0.2 m (0.5 ft) above the deck (low). Bulkhead, overhead deck, and flame temperature data were not provided to the SCS system. These sensors were included to assist Control Room personnel with test supervision and data analysis. The following compartments were instrumented with air thermocouples:

Main Deck:

1. Passage 1-15-1-L;
2. Passage 1-15-4-L;
3. CSMC/Repair 8 (1-15-0-C);
4. Emergency Generator Room (1-21-1-Q);
5. Engineering Storeroom (1-26-1-A);
6. Electronics Storeroom (1-23-0-A);
7. Radar Room No. 5 (1-23-2-C);
8. Passage 1-22-1-L;
9. Passage 1-22-2-L;
10. Passage 1-25-1-L;
11. Passage 1-25-2-L; and
12. Escape Trunk 3-29-3-T.

Second Deck:

1. Repair 2 (2-9-1-Q);
2. DC Equipment Storeroom (2-9-2-A);
3. SCBA Storeroom (2-9-4-A);
4. Passage 2-9-0-L;
5. CPO Living Space (2-15-0-L);
6. CIC (2-18-0-C);
7. Vestibule into CIC;
8. Passage 2-15-1-L;
9. Passage 2-15-2-L;
10. Operations Office (2-22-1-Q);
11. Combat System Office (2-22-0-Q);
12. Passage 2-22-1-L; and
13. Passage 2-22-2-L.

Third Deck:

1. Passage 3-12-1-L;
2. Chilled Water Machinery Room (3-11-2-Q);
3. Gunnery Department Office (3-11-4-Q);
4. Crew Living Space (3-15-0-L);
5. Communications Center (3-18-0-C);
6. Radio Transmitter Room (3-22-1-C);
7. Access 3-24-1;
8. Tomahawk Equipment Room (3-23-2-C);
9. Engineering Storeroom (3-24-0-A); and
10. Escape Trunk 5-29-1-T.

Fourth Deck:

1. AMR No. 1 (5-22-0-E);
2. Engineering Operating Station (4-22-1-E); and
3. MMR No. 1 (5-29-0-E).

Hold Level:

1. AMR No. 1 (5-22-0-E); and
2. MMR No. 1 (5-29-0-E).

4.8.2 Smoke Density

Smoke obscuration, which provides a measurement of visibility, was measured using optical density meters (ODMs). The ODMs use an 880-nm infrared (IR) light-emitting diode (IRLED) and receptor arrangement over a 1.0-m (3.1-ft) path length [23]. The ODMs were located in passageways on the Main and 2nd Decks and in Repair 2. They were placed nominally 1.5 m (5 ft) above the deck, close to bulkheads, to minimize disruption to normal personnel traffic. The following areas were instrumented with ODMs:

Main Deck:

1. Passage 1-15-1-L;
2. Passage 1-15-4-L;
3. Passage 1-25-1-L; and
4. Passage 1-25-2-L.

Second Deck:

1. Repair 2 (2-9-1-Q);
2. Passage 2-9-0-L;
3. Passage 2-15-1-L;
4. Passage 2-15-2-L;
5. Passage 2-22-1-L; and
6. Passage 2-22-2-L.

4.8.3 Heat Flux

Total heat flux transducers (calorimeters) were positioned in the Comm Center and AMR No. 1 to measure the incident total heat flux threat to Damage Control personnel during DC operations. Both sensors were positioned 0.9 m (3 ft) above the deck. These data were not provided to the SCS system.

4.8.4 Gas Concentrations

Oxygen, carbon dioxide, and carbon monoxide concentrations were measured using Rosemount NGA 2000 analyzers. Gas samples were drawn continuously from four locations, each at approximately 2.4 m (8 ft) above the deck: CIC, Comm Center, Tomahawk Equipment Room, and Crew Living. Gas samples were filtered and passed through an impingement-type water trap. Additionally, the gas sample passed through cold traps to remove any remaining water.

4.8.5 Air Pressure

Taps for differential pressure transducers were installed in specific compartments, decks, and bulkheads to measure pressure differentials between decks, compartments, and weather. The measured differential pressures provided an indication of the direction (and relative magnitude) of smoke migration throughout the test space. Pressure differentials with respect to ambient provided an indication of the pressure buildup from the fire source and the effectiveness of closure settings.

4.8.6 Water Pressure

Pressure transducers were installed to monitor fire main pressure at 1-19-1, 1-19-2, 2 19-1, 2-19-2, 2-28-1, and 2-28-2.

4.9 Early-Warning Fire Detection System

The EWFD is a multi-criteria device designed to improve the current fire detection capability of COTS smoke detectors. This improvement includes increasing detector sensitivity to fires, decreasing detection time, and increasing reliability through improved nuisance alarm immunity. Work to date has focused on identifying appropriate sensors and candidate multivariant alarm algorithms [24-33].

During the peacetime demonstrations, 14 EWFD prototypes were installed on the second and third decks, as shown in Appendix G. The locations included the Combat System Office, Operations Office, CPO Living, Radio Transmitter Room, Tomahawk Equipment Room, and Engineering Storeroom. Additional EWFD were installed in the passageways on the 2nd and 3rd Decks.

Each prototype detector was installed so that wire leads from each sensor (i.e., multiple sensors per detector) ran to a computer data acquisition system located in the starboard node room on the 2nd Deck. The sensor data were processed using a probabilistic neural network (PNN) algorithm. The output of this algorithm was the probability that a fire event existed. A warning was issued when the probability reached a value of 0.75. The alarm state was triggered if the probability was greater than 0.85 for three or more consecutive predictions. A dedicated personal computer located in the Control Room and connected to the LAN was used to monitor the alarm conditions of all of the early-warning fire detectors. Additionally, data from the EWFD system (i.e., alarm status and probability value) was made directly available to the SCS Compartment Damage Displays via the *Shadwell* LAN.

4.10 COTS Detection System

The DDG 51 Class ships are currently equipped with smoke detectors (photoelectric and ionization) and heat detectors in vital spaces, such as CIC and the Comm Center. Many spaces, such as passageways, are not monitored. A COTS fire detection system, manufactured by Simplex, was installed throughout the test area on the ex-*Shadwell*. The shipboard system consisted of Simplex ionization detectors (Model 4098-9717) and Simplex photoelectric detectors (Model 4098-9714) monitored with a single alarm panel (Simplex Model 4020) and a monitoring console in the Control Room. The Simplex fire alarm system provided time of alarm data for the exposed detectors. The alarm verification feature was not enabled for these detectors. The alarm sensitivity of these detectors was set to 8%/m (2.5%/ft) for the photoelectric detectors and 4.2%/m (1.3%/ft) for the ionization detectors, which are the same settings used in previous test series for this program.

4.11 Video Cameras

Video cameras were installed in compartments and passageways to provide situation awareness for the DCO. Cameras in the PDA were available only to the test team for safety purposes. Images from selected cameras were displayed in the Control Room and recorded on video recorders. By splitting the signal, video images were also accessible to the SCS via the *Shadwell* LAN. Table 3 lists camera locations; Appendix I provides schematics. To simulate the damage from a missile hit, various camera views were made unavailable to the SCS Surveillance Video function during the wartime tests.

4.12 Door Closure Sensors

Door closure sensors were installed on all doors within the test area to provide door status information (Appendix J). Preliminary evaluations were conducted on the ex-*Shadwell* to identify a suitable sensor [35]. Based on these tests, variable resistance sensors manufactured by Novotechnik (Model TR 25) were installed. These sensors were calibrated to show whether doors were open, closed but not dogged, and dogged. A distinct output was also available for cases in which there was no signal (i.e., to simulate when the sensor or wire was damaged by the blast). Since the sensors were not able to withstand high temperatures (100°C (212°F) was the maximum temperature recommended by the manufacturer), they were not positioned on doors to fire compartments. Door closure sensor data were made available to the SCS Compartment Displays over the *Shadwell* LAN.

4.13 Supervisory Control System

The SCS developed by MPR Associates, Inc. was used during the FY01 demonstrations. The SCS is a hierarchical distributed control system that monitors and controls multiple ship systems and enables a human supervisor to interact with ship systems to manage human actions so that responses of the systems and the action of personnel complement one another. The SCS performs the following functions:

— Controls Fire Main
— Controls Water Mist system
— Provides fire alarm and fire characterization information
— Provides video surveillance of compartments
— Provides access closure information
— Provides entry of information from verbal reports
— Provides simulated combat system interface with threat status
— Provides the ability to define operational priorities with influence to DC actions

Table 3 — Video Camera Location

Camera	Camera Location and Description
1	Main deck, Passage 1-15-1-L @ FR 15 looking aft
2	Main deck, Passage 1-15-4-L @ FR 16 looking aft
3	Main deck, CSMC/Repair 8 @ FR 23, port side looking forward and starboard
4	Main deck, Passage 1-22-1 @ FR 22 looking aft
5	Main deck, Passage 1-25-1 @ FR 25 looking aft
6	Main deck, Escape Trunk 3-29-3 looking down
7	Second deck, Repair 2 at FR 11, port side looking forward and starboard
8	Second deck, Passage 2-9-0-C at FR 11 looking aft and starboard
9	Second deck, Passage 2-9-0-C at FR 13, starboard side looking port
10	Second deck, Passage 2-15-1-L @ FR 15 looking aft
11	Second deck, Passage 2-15-1-L @ FR 29 looking forward
12	Second deck, Passage 2-15-2-L @ FR 15, looking aft
13	Second deck, Passage 2-22-2-L @ FR 29, looking forward
14	Second deck, Passage 2-15-0-L @ FR 15, looking port across CPO Living Space
15	Second deck, Passage 2-18-0 @ FR 19, looking port across CIC
16	Second deck, Operations Office @ FR 27, starboard side looking forward and port
17	Second deck, Combat Systems Office @ FR 29, port side looking forward and starboard
18	Third deck, Passage 3-12-1-L @ FR 12, centerline looking aft and starboard
19	Third deck, Chilled Water Machinery Room @ FR 11 looking aft
20	Third deck, Gunnery Department Office @ FR 11 looking aft
21	Third deck, Crew Living @ FR 17, starboard side looking port
22	Third deck, Comm Center @ FR 20, starboard side looking port
23	Third deck, Radio Transmitter Room @ FR 23, starboard side looking port
24	Third deck, Engineering Storeroom @ FR 27, starboard side looking port
25	Third deck, Tomahawk Equipment Room @ FR 26 looking forward and port
26	Third deck, Escape Trunk 5-29-1 looking down
27	Third deck, MMR No. 1 at FR 30, on port catwalk looking starboard and down
28	Fourth deck, AMR No. 1 @ FR 22 looking aft
29	Fourth deck, Engineering Operation Station @ FR 23 looking aft
30	Fourth deck, MMR No. 1 @ FR 29 looking forward through AMR No. 1
31	Fourth deck, MMR No. 1 @ FR 29, port side looking starboard
32	Hold level, AMR No. 1 @ FR 22 looking aft
33	Hold level, MMR No. 1 @ FR 29 looking forward through AMR No. 1
34	Hold level, MMR No. 1 @ FR 29, port side looking starboard

— Provides displays to characterize damage
— Provides decision aids to assist with managing DC response
— Provides casualty simulation to facilitate training.

The SCS analyzed the available data to characterize the casualty and presented a visual display summarizing the situation. The primary display focused on the information needed to assess the casualty and manage the damage control response. This information included a pre-hit information screen (which determined the time to missile impact), a view of the test area (which displayed the damaged areas), and a decision aid screen (which displayed the alarms/events and suggested actions). Other displays provided supplemental information regarding the damage, including video surveillance and a fire summary screen, which summarize the severity of the fires present.

Based on the information gathered by the sensors installed throughout the test area, the SCS generated decision aids for use by the DCO. The visual displays were supplemented with text messages providing details on alarms and/or significant events. For each alarm or significant event, the SCS displayed decision aids or recommended actions to help manage the casualty. Recommended actions were not automated and required interaction on the part of personnel in DCC. These actions included activating the SES, sending personnel to set manual fire boundaries in areas where water mist was not available, and dispatching personnel to perform indirect/direct fire attacks. Automated actions such as setting fire boundaries with water mist or isolating fire main ruptures occurred automatically, without any input on the part of the DCO. Reference 36 provides additional information about the DC-ARM SCS functions and control system architecture.

4.14 Damage Control Communications

Wirefree communications (WIFCOM), sound-powered phones (2JZ circuit), and the ships' general announcing system 1MC were used for damage control communications. Communication links were separated and segregated by DC function to facilitate the flow of information within the DC organization. The communication plan included:

- The DCO, DCC Communicator/ Plotter, and BDAT used WIFCOM (channel 6). The BDAT investigation teams would receive information *from* the DCO, and the DCC Communicator/ Plotter would receive information *returned* to DCC.
- The Repair Station Communicator and the DCC Console Operator used the sound-powered phone circuit (2JZ). This communications link enabled the DCC Console Operator to convey commands from the DCO to the Casualty Coordinator at Repair 2.
- The Casualty Coordinator and the Repair 2 Team Leaders used WIFCOM (channel 2). This communication link enabled the Casualty Coordinator to manage and direct the actions of the Attack and Support teams.

5. OVERVIEW OF PEACETIME SCENARIOS AND PROCEDURES

5.1 Peacetime Scenario Overview

The purpose of the peacetime demonstrations was to illustrate that the DCO had improved situation awareness and to further refine the RRT doctrine. A total of five peacetime scenarios were demonstrated. As shown in Table 4, the demonstrations incorporated both nuisance and real fire sources.

Table 4 — Matrix for Peacetime Demonstrations

Demo ID	Location	Source Type	Description
arm3p01	Passage 3-12-0	Real	Trash can fire
arm3p02	Passage 29-0	Real	Smoldering electrical cable
	CPO Living	Nuisance	Toasting Pop-Tarts®
arm3p03	Operations Office	Real	Computer monitor
	3-39-0	Nuisance	Diesel engine exhaust
arm3p04	Tomahawk Equipment Room	Real	Smoldering electrical cable
	CPO Living	Nuisance	Grinding painted steel
arm3p06	Operations Office	Real	Smoldering bedding
	Engineering Storeroom	Nuisance	Welding

5.2 Setup for Peacetime Demonstrations

The peacetime demonstrations included small, but growing, Class A fires and nuisance sources. The nuisance sources were included to evaluate the EWFD and SCS capabilities to distinguish between real and false fire events. The scenarios used either a single source or multiple sources in separate compartments.

Scenario arm3p01 used a single source that consisted of a trash can fire filled with newspaper and other miscellaneous items. Scenarios arm3p02 through arm3p06 used multiple sources in separate compartments. Scenario arm3p02 consisted of a smoldering cable in the Repair 2 passageway and toasting Pop-Tarts® in CPO Living. Scenario arm3p03 consisted of a computer monitor fire in the Operations office and diesel engine exhaust in the Engineering Storeroom as a potential nuisance source. Scenario arm3p04 included a smoldering electrical cable fire in the Tomahawk Equipment Room and grinding steel in CPO Living as a potential nuisance source. Finally, scenario arm3p06 included smoldering bedding in the Operations Office and welding steel in the Engineering Storeroom as the potential nuisance source.

5.3 Procedures for Peacetime Demonstrations

During the peacetime demonstrations, it was assumed that the ship was at Condition III and modified condition ZEBRA set. The DC Watch Supervisor was stationed in DCC prior to the start of the test. The fire main was set at condition YOKE with one fire pump on line and the other pump in standby. These initial conditions are consistent with current Fleet practice and similar to the conditions used in previous testing. The SCS operational priorities function was adjusted to Save the Ship operation, which focuses the DC priorities to minimizing damage and hazards to ship equipment and crew [36].

When an alarm warning from the EWFD system was received (probability = 75%), the SCS called up the video of the compartment and the DC Watch Supervisor called away the Rapid Response Team to investigate the appropriate space. For tests arm3p03 through arm3p06, the SCS Surveillance Video software was adjusted to display a view of the fire compartment when the EWFD system reached a probability of

60%. This lower probability value was selected so the system would have an adequate amount of time to access the video before EWFD alarm condition (85%) was reached.

After the fire was called away by the DC Watch Supervisor, the DCO reported to DCC and took charge of the incident. Data from the early warning fire detectors and SCS Surveillance Video and Compartment Damage Displays were used to determine the severity of the situation. Once the source of the alarm was identified by the RRT, the fire was extinguished and overhauled as required. The demonstration was then secured. A debrief was conducted at the conclusion of the final peacetime demonstration.

6. OVERVIEW OF WARTIME SCENARIOS AND PROCEDURES

The purpose of the wartime tests was to demonstrate the capability of the DC-ARM systems to contain damage to the primary damage area. Demonstrations differed from each other by varying the fire scenarios within the PDA, the involvement of various APDA compartments (i.e., having sympathetic ignition in different compartments), and by incorporating various fire main ruptures and flooding scenarios. In addition, different faulty data schemes were applied to varying compartments during the tests. Figures 15 through 19 provide an overview of PDA and APDA compartments and Table 5 describes the fire scenarios at the eight locations.

6.1 Basis for the Wartime Damage Scenario

The basis for the wartime damage scenario was developed using information gleaned from the Battle Damage Estimator model developed by NSWC Carderock [3], the USS *Stark* incident [6], and ex-USS *Dale* weapon effect tests [7]. Also, fire spread guidelines based on experimental data were incorporated [37-42].

Basic assumptions included:

1. The ship (assume DDG 51 Class) is hit by a medium antiship missile.
2. The missile hit is survivable.
3. Mission is the top priority, therefore, HM&E (hull, mechanical, and electrical) systems must be maintained to support the mission.
4. Watertight closures are set at the time of the hit (i.e., Condition I or ZEBRA).
5. APDA compartments may be unmanned.
6. After the missile hit,
   — propulsion and power are still available,
   — the computer network (if damaged) has self-healed and is available,
   — any ruptures in the water mist system have been isolated, and
   — all DC personnel survive.
7. Flashover may occur within 5 minutes after ignition inside compartments with Class A materials. For cases where Class B fuel tanks or flammable liquid piping has been breached by the blast overpressure, the time to flashover may be quicker, approximately 2 to 5 minutes [37-39].
8. Vertical fire spread may occur within 5 minutes after the compartment below has reached flash over [37, 40-42]. This assumption is based on combustible material that is in contact with the deck.
9. Horizontal fire spread may occur within 9 minutes after the adjacent compartment has reached flashover [37, 41-42]. This assumption is based on combustible material that is in contact with the bulkhead.
10. The primary objective is to contain damage.

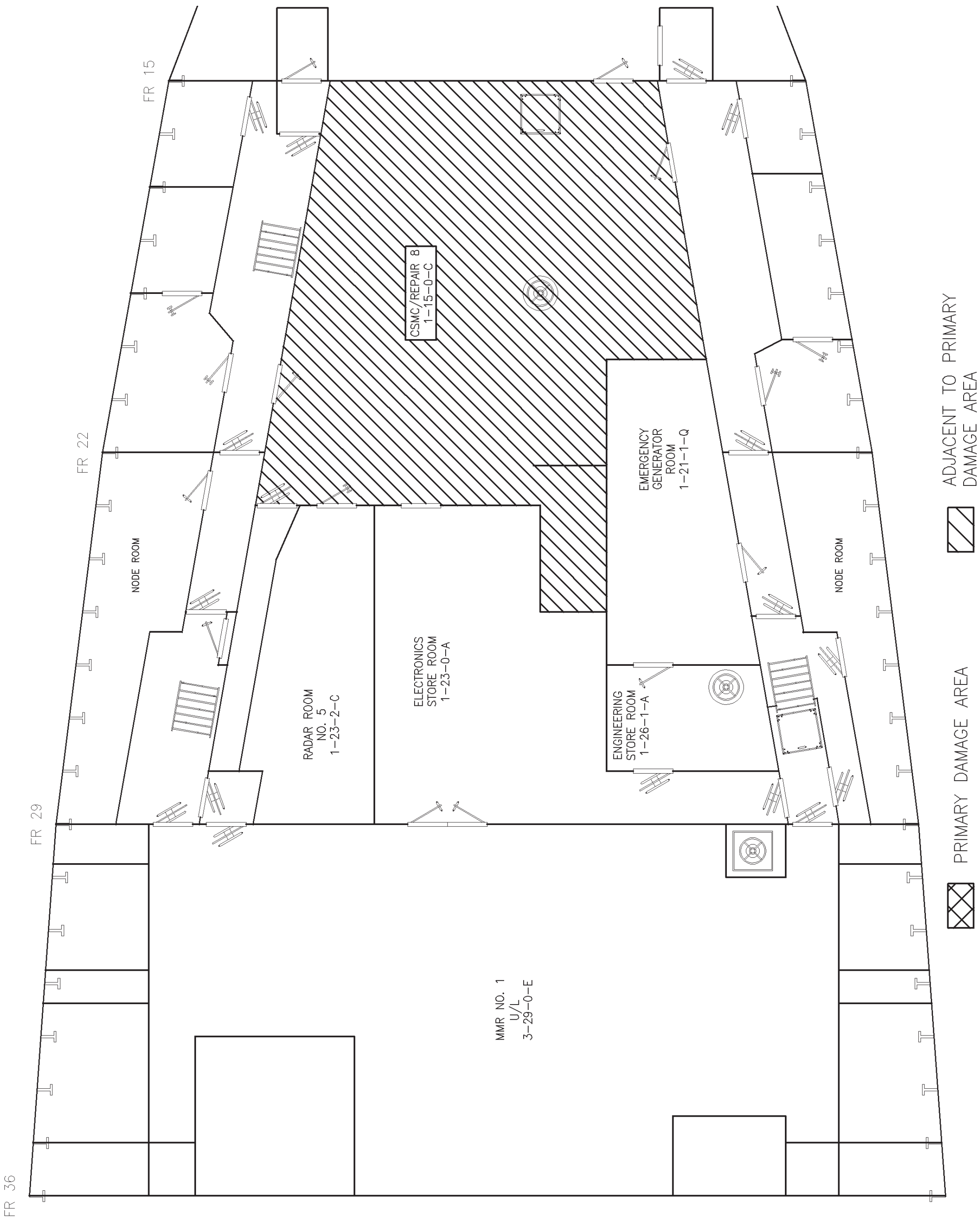


Fig. 15 — Compartment damage classification for Main Deck

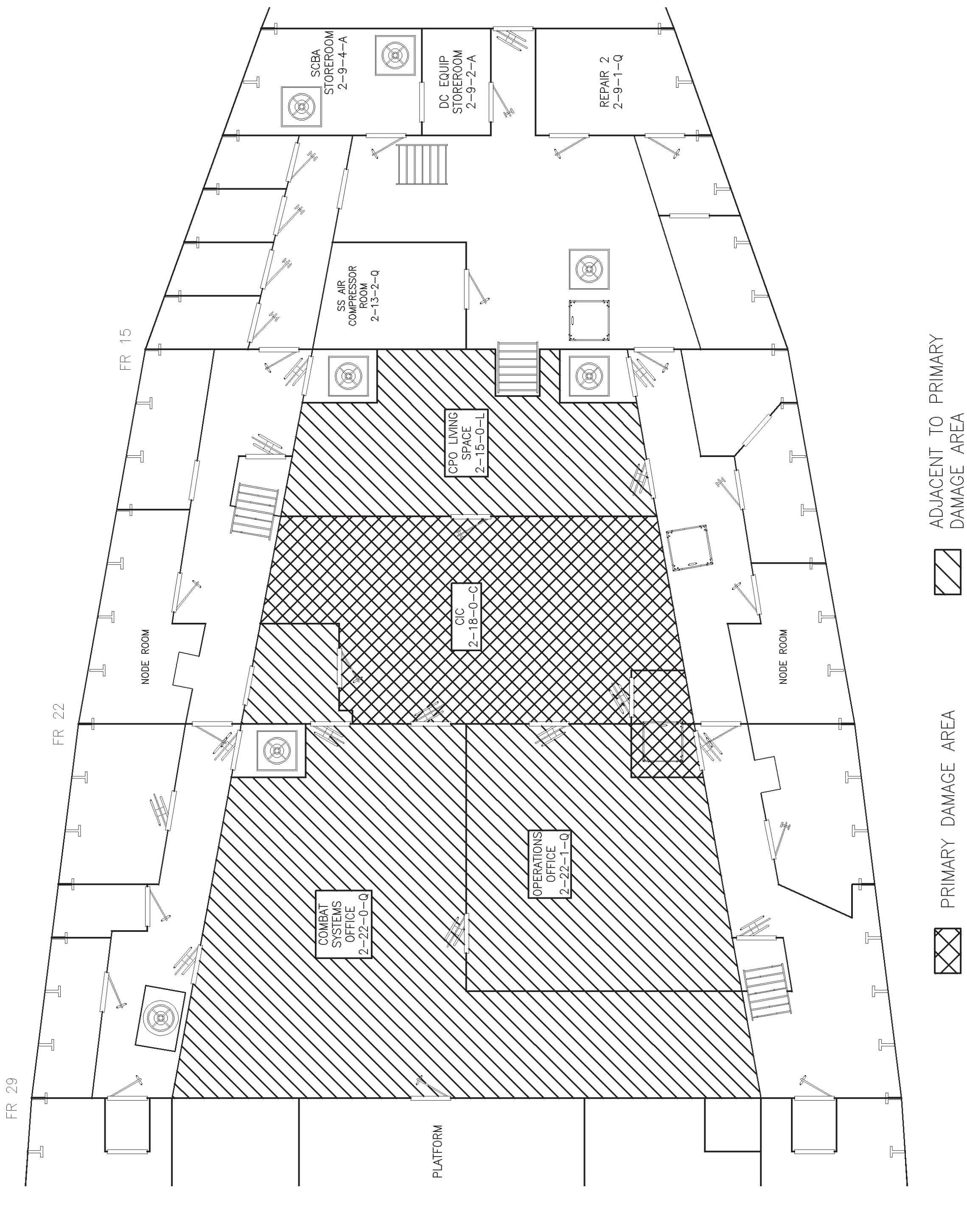


Fig. 16 — Compartment damage classification for Second Deck

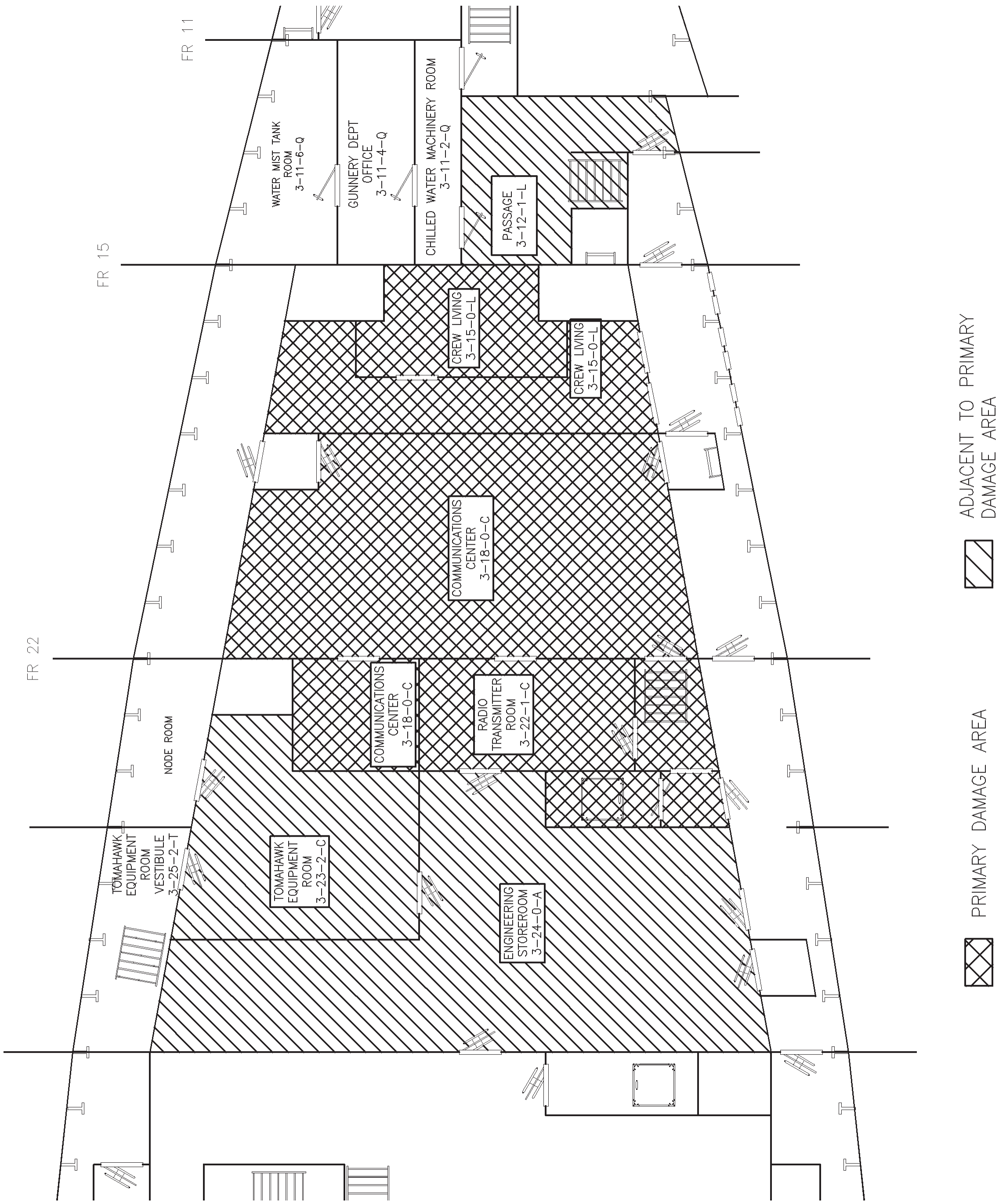


Fig. 17 — Compartment damage classification for Third Deck

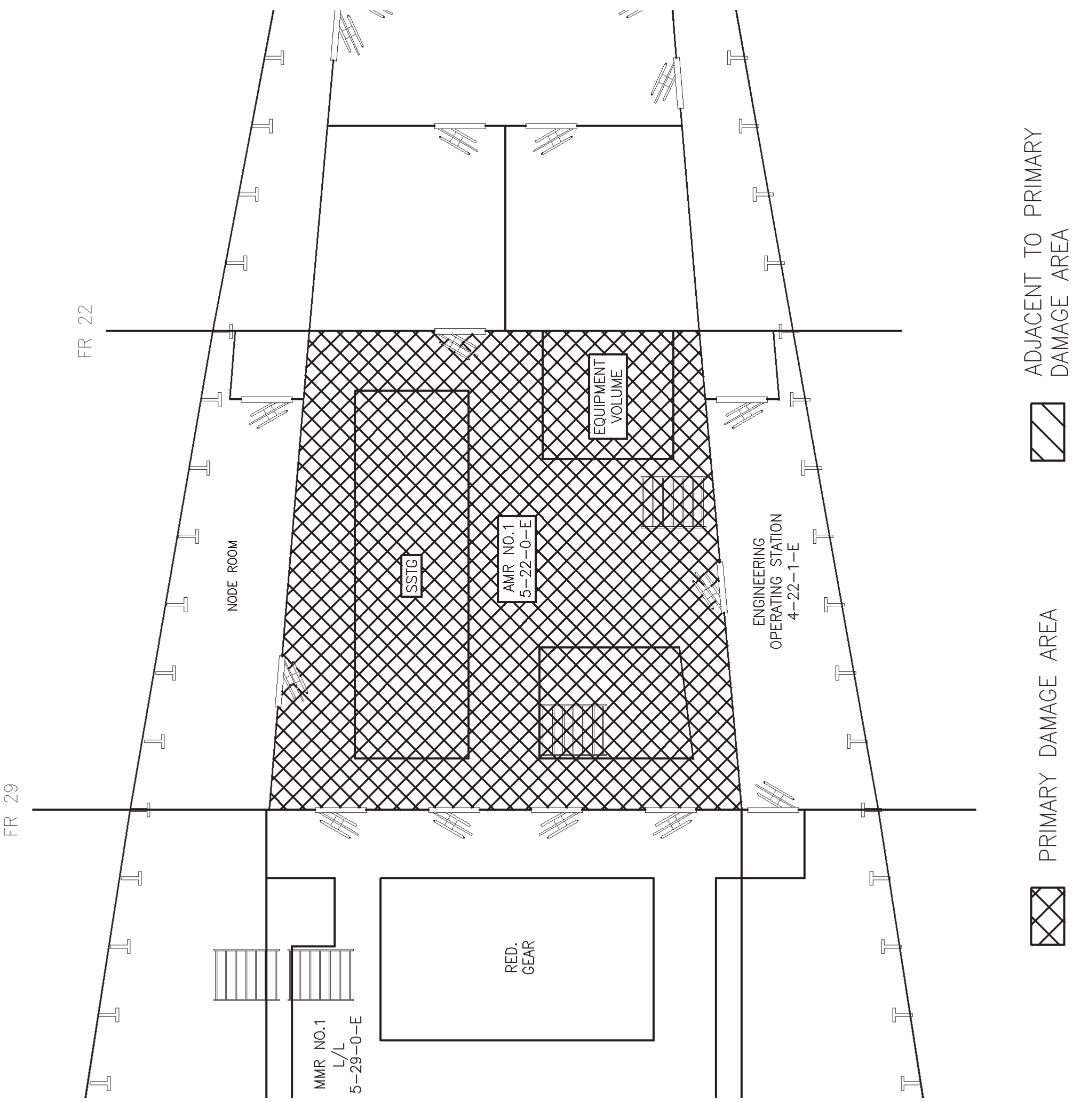


Fig. 18 — Compartment damage classification for Fourth Deck

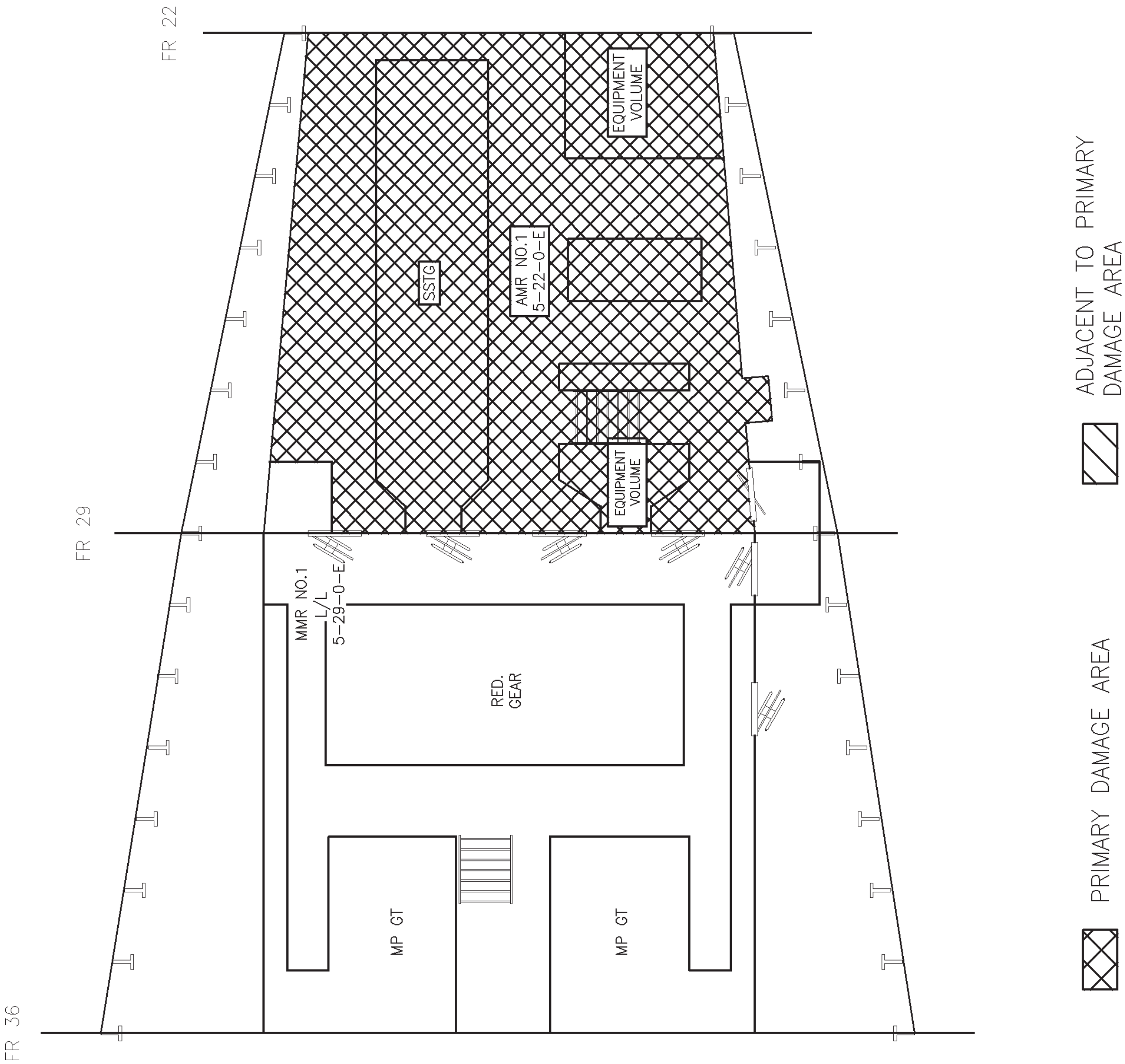


Fig. 19 — Compartment damage classification for Hold Level

Table 5 — Fire Descriptions

Location Number	Location	Primary Damage Area (PDA) or Adjacent to Primary Damage Area (APDA)	Description
1	Comm Center/Crew Living Space[1]	PDA	Large heptane spray fire[2] and 1 large wood crib[3]
2	AMR No. 1	PDA	F76 pan fire[4]
3	Comm Center	PDA	Small heptane spray fire[5]
4	Radio Transmitter Radio	PDA	1 small wood crib[6]
5	Tomahawk Equipment Room	APDA (horizontal spread)	Bin filled with Class A material
6	Engineering Storeroom	APDA (horizontal spread)	Bin filled with Class A material
7	CPO Living Space	APDA (vertical spread)	Bedding material
8	Combat System Office	APDA (vertical spread)	Bin filled with Class A material

[1] Flames from the Comm Center/Crew Living fire extended into CIC since the blast panels in the overhead were removed.
[2] Large heptane spray fire used Bete FF093 nozzle at 345 kPa (50 psi).
[3] Large wood crib was composed of 10 rows of 1.2-m (4-ft) long sticks, 3.8-cm (1.5-in.) square, with 10 sticks per row and supported on a metal stand approximately 0.6-m (2-ft) above the deck. For demonstration arm3w08, two large wood cribs were used; one crib was composed of 12 rows of 1.2-m (4-ft) long sticks, 3.8-cm (1.5-in) square, with 10 sticks per row. The second crib was composed of 11 rows of (4-ft) long sticks, 3.8-cm (1.5-in) square with 10 sticks per row.
[4] Pan with dimensions 2.4×0.9 m (8×3 ft)
[5] Small heptane spray fire used Bete P32 nozzle at 345 kPa (50 psi).
[6] Small wood crib was composed of 10 rows of 0.6-m (2-ft) long sticks, 3.8-cm (1.5-in.) square, with 6 sticks per row and supported on a metal stand approximately 0.3-m (1-ft) above the deck. For demonstration arm3w08, the wood crib was composed of 19 rows of 0.6-m (2-ft) long sticks, 3.8-cm (1.5-in.) square, with 6 sticks per row.

The wartime scenario begins with the ship's Commanding Officer setting Combat Condition YELLOW (i.e., a potential hostile threat is in the area). This increased readiness condition requires the Blue Team to man Repair 2. When an attack is deemed imminent, Combat Condition RED is announced and the Repair Party, BDAT, and DCC organizations report to their designated Condition I battle stations. At time zero, a moderately sized antiship missile hits the Communications Center. The blast overpressure destroys all surrounding bulkheads and creates deck openings into CIC and AMR No. 1. This weapon damage effectively makes the Comm Center, AMR No. 1, Radio Transmitter Room, Crew Living, and CIC one large space. In reality, the bulkhead between the Tomahawk Equipment Room and the Comm Center would also likely be destroyed. For the FY01 demonstration, it was assumed that the bulkhead remains intact. This permitted additional flexibility for fire spread to APDA compartments. The SCS operational priorities function was adjusted to Maintain Mission Capability operation. This adjustment then influences the Damage Control Priorities to continue to Fight the Ship [36].

The warhead detonation was assumed to ignite the Class A and Class B materials in the Comm Center/ CIC. Figures 20 through 22 show the fire locations for the wartime event. Combustibles in the Radio Transmitter Room could ignite in approximately 1 to 2 minutes as the result of the Comm Center fire and breached bulkheads. This 2-minute ignition time is not a firm number (i.e., not based on actual testing), but is representative of the ignition of combustibles located nearby. Approximately 2 to 5 minutes after the detonation, AMR No. 1 could reach flashover. Five minutes after the blast, the Comm Center and CIC could reach flashover and begin heating the surrounding bulkheads and decks, transferring heat to nearby compartments. Seven minutes after the detonation, the Radio Transmitter Room and the Crew Living Space could reach flashover.

Fire spread to APDA compartments could occur at approximately 10 minutes when combustibles in CSMC/Repair 8 ignite (as the result of heating of the deck by the flashover fire in CIC). Combustibles in CPO Living may ignite at 12 minutes, followed by those in the Tomahawk Equipment Room, Combat System Office, and Operations Office at 14 minutes. Approximately 15 minutes after the detonation, CSMC/ Repair 8 could reach flashover. At 16 minutes, combustible materials in the Engineering Storeroom could ignite due to horizontal heating from the Radio Transmitter Room. One minute later (at 17 minutes), the CPO Living Space could reach flashover. At 19 minutes, the Tomahawk Equipment Room, Operations Office, and Combat System Office could reach flashover. At 21 minutes, the Engineering Storeroom could reach flashover.

6.2 Setup for Wartime Demonstrations

A 3.5-MW heptane spray fire and two large wood cribs were staged in the Comm Center/ Crew Living Space. Figure 23 shows this setup. In addition, a 400-kW heptane spray fire was directed at the FR 24 bulkhead to provide localized heating.

As shown in Fig. 24, a small wood crib was staged in the Radio Transmitter Room. This crib was positioned adjacent to FR 24 to provide heating of the bulkhead and overhead. As such, sympathetic ignition in the Engineering Storeroom and Combat System Office was possible. Spray fires were initiated using a small pan of heptane located near the spray. For demonstration arm3w05, a 2.8-MW F76 pan fire was also staged in AMR No. 1. The pan was located on the hold level and had dimensions of 2.4 × 0.9 m (8 x 3 ft). A small amount of heptane was used as an accelerant when the pan was lit.

Fire was spread to APDA compartments by staging combustible material in the APDA compartments. It was expected that if preemptive actions were taken (i.e., water mist system activated or boundaries manned by DC personnel), the fires would either be small or not ignite. Fuel packages in APDA compartments primarily consisted of bins filled with Class A materials. The bins were constructed of a strong wire mesh with expanded metal. They had overall dimensions of 0.9 m wide × 0.5 m deep × 1.2 m high (3 ft wide × 1.5 ft deep × 4 ft high). Approximately 12 wood sticks (3.8 cm × 3.8 cm × 0.6 m (1.5 in. × 1.5 in. × 2 ft)) were placed in a bin filled with excelsior. These bins were located where sympathetic ignition was likely in the time frame discussed in Section 6.1 (less than 14 minutes after the missile hit). Four bunks with bedding materials were used as the fuel packages in CPO Living, and combustible office furnishing were provided in the Combat System and Operation Offices.

Fire main ruptures were used as part of the wartime demonstrations. Low-volume rupture locations were outside of the PDA (e.g., Operations Office 2-23-1-C and second deck starboard passageway 2-20-1-L). Main Space flooding was also included during these tests. Prior to demonstrations arm3w05 through arm3w07, the escape trunk in AMR No. 1 (5-29-1-E) was filled with water to simulate a flooded space. Once the flooding in the escape trunk was discovered by the investigators, Safety Team personnel initiated progressive flooding into MMR No. 1.

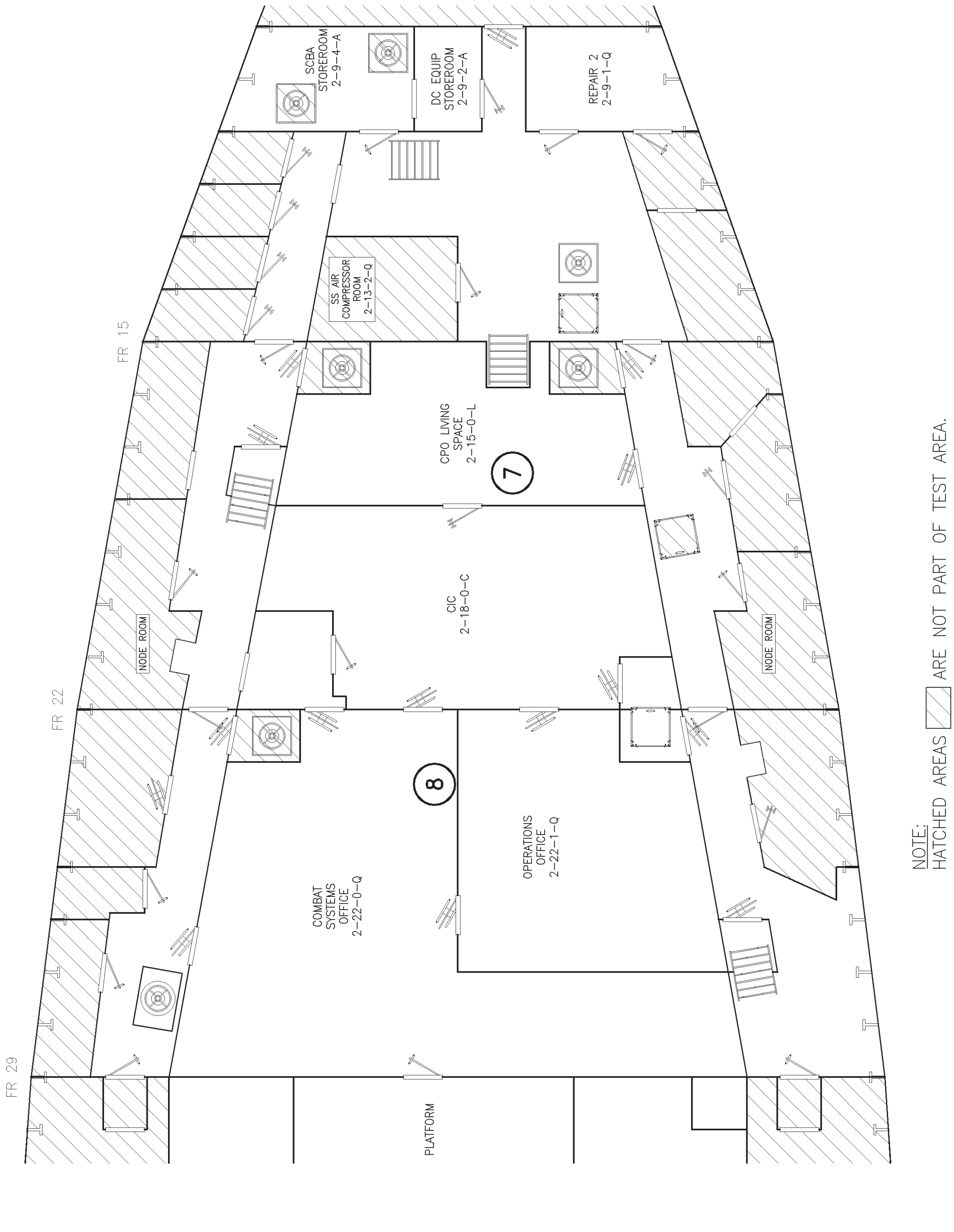


Fig. 20 — Second Deck fire locations

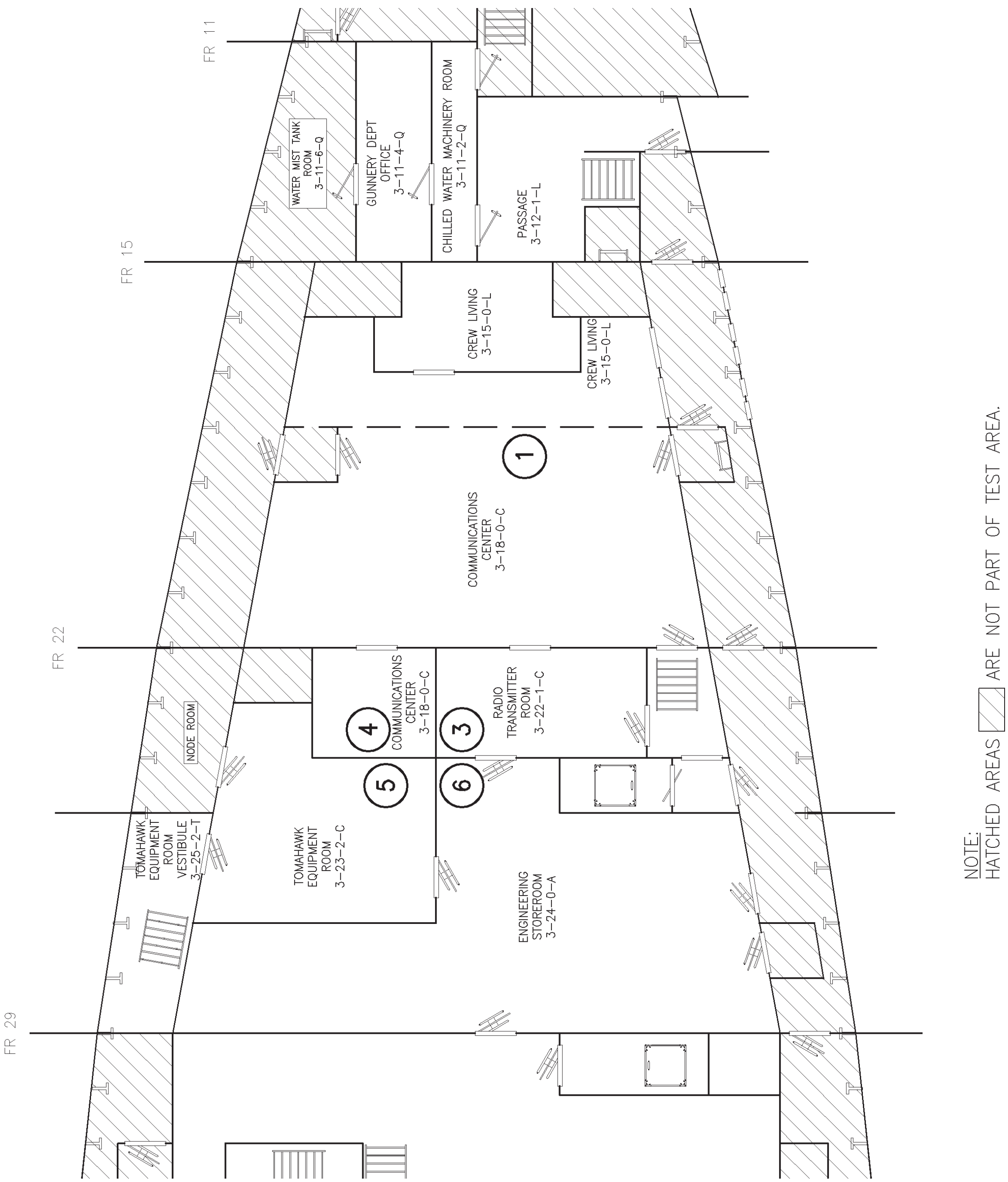


Fig. 21 — Third Deck fire locations

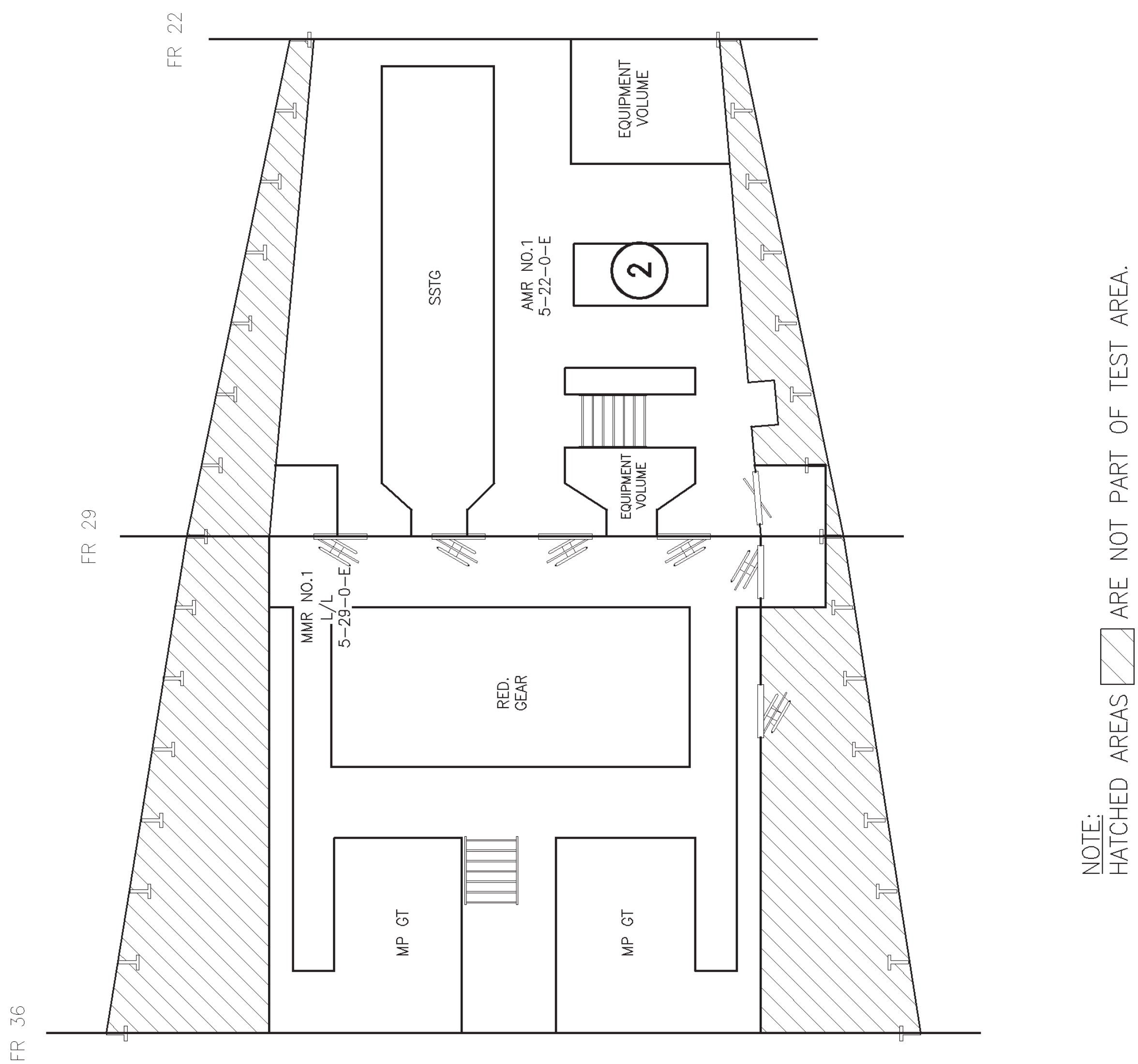


Fig. 22 — Hold Level fire locations

Fig. 23 — Wood crib for Comm Center

Fig. 24 — Wood crib for Radio Transmitter Room

It was assumed that the blast would destroy all sensor, pipe, and ductwork located in the PDA (i.e., Comm Center, Crew Living Space, Radio Transmitter Room, and CIC). This damage included the loss of the water mist suppression system, ex-*Shadwell* sensors, door closure sensors, video, EWFDs, and COTS detectors in the PDA. For this test series, the level of damage varied. This variation permitted a more complete evaluation of the DC-ARM systems. Damage to some of these systems was accomplished by physically removing sensors or water mist nozzles. Ex-*Shadwell* sensors were damaged electronically as described in Section 4.8. Since the fire main was not located inside the PDA, ruptures outside the PDA were incorporated. The smoke ejection system was fully operational during all tests. Four wartime demonstrations were conducted (arm3w05 through arm3w08). Table 6 summarizes these demonstrations; Appendix F lists the damaged sensors.

Table 6 — Matrix for Wartime Demonstrations

Demo Name	Primary Damage Area Fires	Locations for Sympathetic Ignition	Location of Fire Main Rupture	Machinery Space Flooding
arm3w05	AMR No. 1 - F76 pool fire Comm Center - Large spray fires and wood crib Radio Transmitter - Wood crib	Engineering Storeroom Combat System Office Tomahawk Equipment Room CPO Living	Ops Office	No
arm3w06	Comm Center - Large and small spray fires and wood crib Radio Transmitter - Wood crib	Engineering Storeroom Combat System Office Tomahawk Equipment Room CPO Living	N/A	Yes
arm3w07	Comm Center - Large and small spray fires and wood crib Radio Transmitter - Wood crib	Engineering Storeroom Combat System Office Tomahawk Equipment Room CPO Living	2nd Deck Starboard Passage	Yes
arm3w08	Comm Center - Large and small spray fires and 2 wood cribs Radio Transmitter - Wood crib	Engineering Storeroom Combat System Office Tomahawk Equipment Room CPO Living	Ops Office	No

For the demonstrations, it was assumed that no personnel within the PDA would survive either the direct or indirect effects of the missile hit. As a result, search and rescue operations within the PDA were not necessary.

Based on previous data, most accesses within the PDA would probably be blocked [7]. Furthermore, debris, such as ductwork, would cover the deck. This would make it difficult for personnel to access the PDA quickly. Damage to the doors and hatches in the PDA was simulated by chaining them shut on the inside or using a metal slide stop.

6.3 Procedures for Wartime Demonstrations

During the wartime demonstrations, the combat system generator was used to simulate a missile launch. The SCS Pre-hit function identified that a hostile aircraft was in range. Based on pre-hit calculations, the

time to impact and predicted damage were identified. At time zero (time of missile strike), damage was initiated to the appropriate ex-*Shadwell* sensors and the fires in the PDA were ignited. The fire main rupture was initiated within 1 to 2 minutes of the missile hit. Prior to the demonstration, the appropriate accesses were jammed, and video cameras, COTS detectors, EWFDs , and door-closure sensors were removed throughout the primary damage area.

Once the missile impacted the ship, the SCS Damage Characterization function identified the PDA and APDA. The SCS Automated Decision Aids then began to provide the DCO recommendations. The DCO oversaw DC operations by responding to the decision aids and monitoring conditions in the APDA compartments by using the SCS Compartment Damage Displays and Surveillance video. The DCO also allocated personnel as recommended by the SCS (i.e., setting manual boundaries, performing indirect/direct attack). The SCS Water Mist Control function automatically set fire boundaries in areas where the water mist system was available. In addition, fire main ruptures were automatically isolated by the SCS Fire Main Control function.

Indirect attack of fires within the PDA was initiated during the demonstrations once boundaries were set and damage was contained. An indirect attack was made on CIC and the Comm/Center through CSMC/ Repair 8. Rather than cutting a hole in the deck for the fire hose, WTS 1-18-0 was opened. Direct attack of the fire in the Comm Center/AMR No. 1 was initiated once the indirect attack was complete.

7. MEASURES OF PERFORMANCE

To evaluate the DC-ARM system capabilities, performance goals and measures of performance were developed. These criteria account for various actions that must be taken to mitigate the casualty and restore the ship to normal operating conditions. The performance goals used for the FY98 and FY00 demonstrations defined times for specific actions to be accomplished. These actions consisted of tasks such as isolating fire main ruptures and setting vertical and horizontal fire boundaries. A different philosophy was used to develop goals for the FY01 demonstration. Rather than developing specific times that must be met, the philosophy was shifted to an as-needed basis. For example, a fire main rupture was not considered unacceptable until the fire main was needed (for vital loads or fire-fighting operations) or flooding became a problem.

The peacetime performance goals included the following:

1. Fires should not exceed an energy release rate of 50 to 200 kW,
2. Fires should not spread to material outside of the initial ignition location,
3. Fires should be extinguished by using portable extinguishers (with water mist as a backup), and
4. Fires should be handled by 2 to 6 people wearing coveralls (Primary Responders arrive without breathing apparatus).

By meeting these objectives, the amount of damage was limited and the number of personnel required was minimal. In addition to these objectives, it was also important to minimize or eliminate the occurrence of false alarms. A high percentage of false alarms may lead to poor manpower utilization and the tendency to ignore alarms.

The wartime performance goals included:

1. Contain damage to the PDA
    - Fires ignited in the APDA compartments should not exceed an energy release rate of 50 to 200 kW
    - Tenability should be maintained in APDA compartments at all times
    - Indirect attacks of the PDA should be used to reduce threat
2. Maintain visibility in passageways at a minimum of 6.1 m (20 ft) at all times.

Conditions were deemed tenable if the temperature did not exceed 80°C (175°F). This criterion is based on the effects that elevated temperatures can have on humans and electronic equipment. A study conducted by Veghte [43] indicated that a temperature of 48°C (118°F) could result in skin pain. Another study indicated that a range of temperatures between 45°C (113°F) and 72°C (162°F) could result in injury to exposed skin [44]. However, if the skin is adequately protected, higher temperatures will likely be tenable. Since the DC personnel were outfitted in coveralls, flash gear, and breathing masks, their skin was not exposed. Additionally, National Fire Protection Association (NFPA) 75, "Standard for the Protection of Electronic Computer/Data Processing Equipment," specifies temperatures at which damage can occur to electronics [45]. Damage to computer equipment may occur when temperatures exceed 80°C (175°F).

Fleet participants actively took part in the DC-ARM demonstration exercises to help test and evaluate the DC-ARM systems and reduced manning doctrine in a realistic shipboard damage environment. The Fleet participants included representatives from: Afloat Training Group (ATG) MAYPORT, Fleet Training Center (FTC) MAYPORT, ATG ATLANTIC, Surface Warfare Officers School (SWOS) Command, USS *Ticonderoga* (CG 47), USS *Cole* (DDG 67), and the PCU *Shoup* (DDG 86). The Human Subjects Review Board at the Bureau of Medicine and Surgery (BUMED) approved the human subject testing protocol [46].

8. PEACETIME DEMONSTRATION RESULTS

Five peacetime demonstrations were conducted between September 10 and 11, 2001. Table 7 summarizes the detection times for the EWFDs and the COTS smoke detectors.

Table 7 — Summary of EWFD and COTS Detection Times for Peacetime Demonstrations

Demo ID	Description	Time after Initiation of Source			
		EWFD		COTS Alarm	
		Warning	Alarm	Photo	Ion
arm3p01	Trash can with bathroom trash	1:14	1:24	DNA	2:04
arm3p02	Smoldering electrical cable	2:11	2:11	3:39	DNA
	Toasting Pop-Tarts®	*DNA*	*DNA*	*DNA*	*DNA*
arm3p03	Smoldering Computer Monitor	3:46	3:50	4:51	4:39
	Diesel Engine Exhaust	*DNA*	*DNA*	*DNA*	*DNA*
arm3p04	Smoldering electrical cable	29:14	37:06	27:32	DNA
	Grinding painted steel	*0:53*	*0:53*	*2:00*	*2:52*
arm3p06	Smoldering bedding	12:04	12:05	DNA	DNA
	Welding	*1:22*	*1:22*	*1:04*	*4:20*

Notes: 1. DNA - Did Not Alarm
2. *Nuisance sources noted in italics.*

The following sections provide an overview of the events that occurred during the peacetime demonstrations. More detailed timelines for each demonstration are included in Appendix K. Times are reported to the nearest second; however, it should be recognized that for some events times are approximated.

8.1 Demonstration arm3p01

8.1.1 Test-specific Parameters

Demonstration arm3p01 consisted of a flaming trash can fire in the forward passageway on the 3rd Deck (Passage 3-12-0-L). The demonstration began when the Safety Team ignited the combustibles in the trash can with a lighter. The hatch between the 2nd and 3rd Decks (QAWTH 2-13-1) was open during this test.

8.1.2 General Results

A warning was issued by the EWFD in Passage 3-12-0, 1 minute, 14 seconds after the trash fire was initiated. Ten seconds later, the EWFD went into alarm. At 2 minutes, 4 seconds, the COTS ionization detector located in the passageway alarmed. At 2 minutes, 30 seconds, the SCS Compartment Damage Display noted a small fire in Passage 3-12-0-L Within 2 seconds, the fire was called away by the DC Watch Supervisor over the 1MC. Subsequently, the SCS Surveillance Video displayed a video image of the passageway.

At 3 minutes, 27 seconds, the RRT Primary Responders arrived on-scene and began to extinguish the fire using a portable fire extinguisher. Thirty-nine seconds later, the RRT Scene Leader reported that the fire had been extinguished. Personnel in the Control Room activated fan E 1-15-1 to ventilate the space and the demonstration was secured.

8.1.3 Use/Effectiveness of DC Systems and Manning

The EWFD reached 75% probability (Fig. 25) and issued a warning 1 minute, 14 seconds after the source was initiated. Ten seconds later, the EWFD went into alarm condition. The collocated COTS ionization detector alarmed 40 seconds after the EWFD alarmed, but the photoelectric detector never alarmed. Considering that many spaces would have photoelectric smoke detectors, the SCS with the EWFD system provided very timely awareness of the fire, which enabled the RRT to quickly correct the casualty and meet all performance goals. It was determined that the SCS Surveillance Video software needed to be adjusted to ensure the video image would display before the EWFD system went into an alarm condition.

8.2 Demonstration arm3p02

8.2.1 Test-specific Parameters

Two sources in separate locations were used during the second peacetime demonstration. The passage outside of Repair 2 on the 2nd Deck was the location for the smoldering electrical cable fire. Five pieces of 0.3-m (1-ft) LSDSGU-9 cable were placed on top of the door to Repair 2. Smoldering was initiated by a calrod, which was placed between the cables. The nuisance source consisted of toasting Pop-Tarts® in CPO Living. Three sets of 8 Pop-Tarts® (24 Pop-Tarts® total) were toasted on high, two times.

8.2.2 General Results

The demonstration began when the calrod heater for the electrical cable was initiated. At 2 minutes, 1 seconds, Safety Team members began toasting the Pop-Tarts® in CPO Living. At the same time, a warning/ alarm was issued by the EWFD system for Passage 2-9-0-L (Fig. 26). An alarm and warning were detected

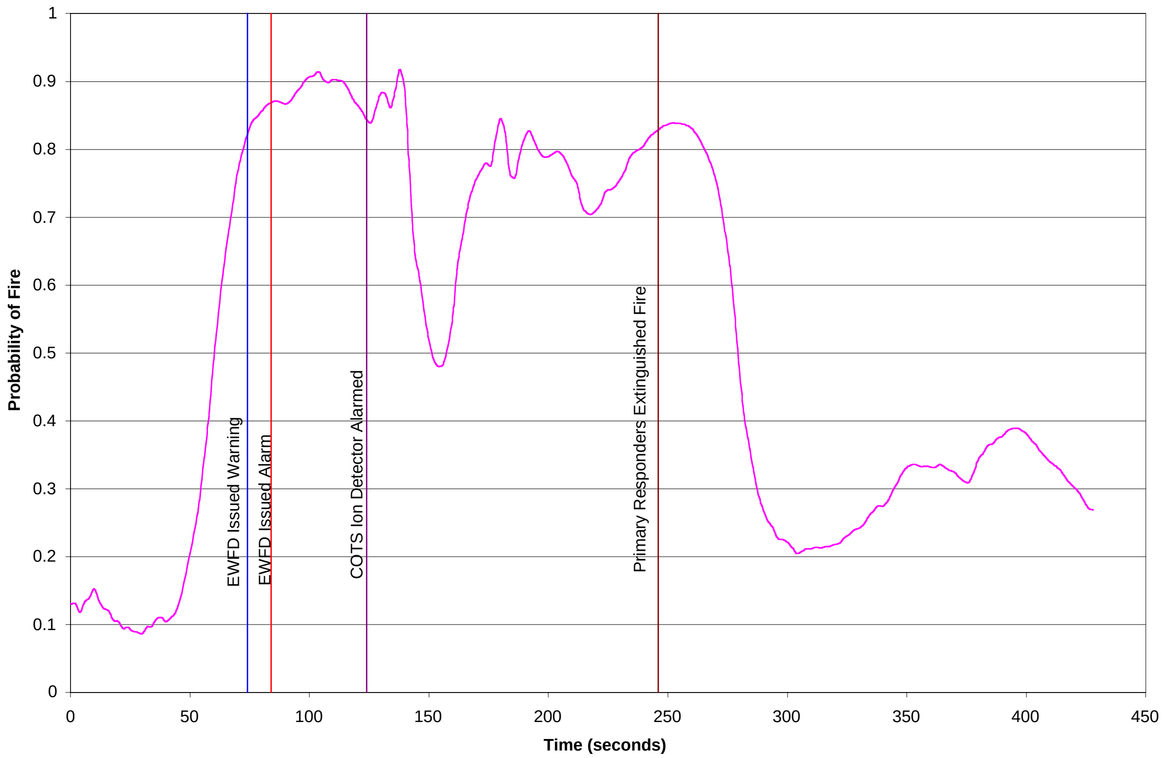


Fig. 25 — Probability of fire, demonstration arm3p01 — flaming trash fire

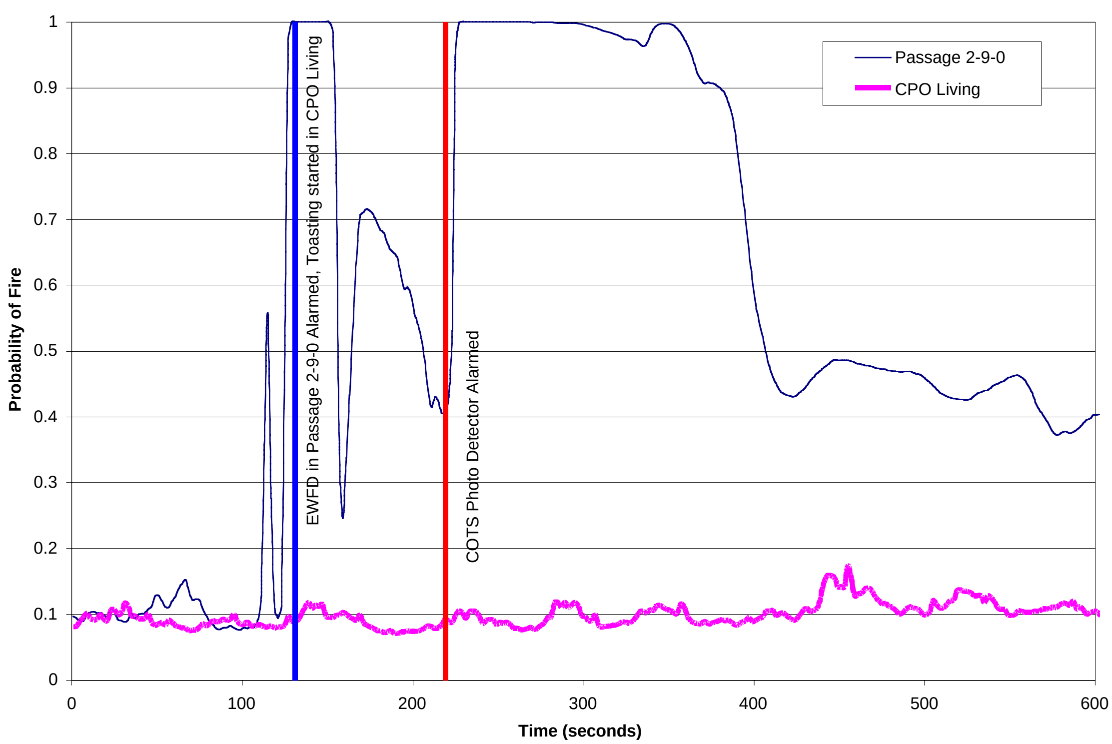


Fig. 26 — Probability of fire, demonstration arm3p02 — smoldering cable (Passage 2-9-0) and toasting Pop-Tarts® (CPO Living)

at the same time due to the fire growth rate. At 2 minutes, 34 seconds, the SCS Compartment Damage Display noted a small fire in Passage 2-9-0-L, based on input received from the EWFD sensors. At this time, the SCS Surveillance Video displayed a video image of the fire compartment. Five seconds later (2 minutes, 39 seconds), the DC Watch Supervisor called away a fire in Passage 2-9-0-L over the 1MC.

At 2 minutes, 53 seconds, the RRT Primary Responders arrived on-scene in the passageway outside of Repair 2. At 3 minutes, 39 seconds, the COTS photoelectric detector #1 installed in Passage 2-9-0-L alarmed. Also at this time, the RRT Primary Responders were observed to be extinguishing the fire using a portable CO_2 extinguisher. The RRT Attack Team and Scene Leader reported to Repair 2 at 4 minutes, 42 seconds. At 4 minutes, 55 seconds, the RRT Scene Leader reported that the fire in Passage 2-9-0-L had been extinguished.

8.2.3 Use/Effectiveness of DC Systems and Manning

For the smoldering fire in Passage 2-9-0-L, the EWFD alarmed 1 minute, 28 seconds before the COTS detectors alarmed. By the time a COTS detector alarmed, the RRT Primary Responders were already on-scene and were extinguishing the fire. Figure 26 shows the probability of fire as measured by the EWFD in Passage 2-9-0-L. Neither the COTS detectors nor the EWFDs alarmed for the nuisance source (toasting Pop-Tarts®) in CPO Living. All performance goals were met in this demonstration.

8.3 Demonstration arm3p03

8.3.1 Test-specific Parameters

The third peacetime demonstration included a nuisance source and a smoldering fire. The source for the smoldering fire was a computer monitor located in the Operations Office. Smoldering of the computer monitor was initiated by a heating element (calrod). The nuisance scenario consisted of the engine exhaust from a diesel engine located in the Engineering Storeroom on the 3rd Deck (3-29-0-E).

8.3.2 General Results

The demonstration was started when the calrod heater in the computer monitor was initiated. The diesel engine was started approximately 20 seconds later. At 1 minute, 28 seconds, a steady stream of smoke was observed from the computer monitor. Three minutes, 46 seconds after initiation, a warning was issued by the EWFD system in the Operations Office. An alarm was issued approximately 4 seconds later. At 3 minutes, 54 seconds, the SCS received the alarm from the EWFD system. At this time, the SCS Compartment Damage Display noted a small fire in the Operations Office, and the SCS Surveillance Video displayed a video image of the fire compartment. The DC Watch Supervisor called away a fire in the Operations Office over the 1MC at 4 minutes, and the RRT Primary Responders were dispatched to respond to the fire.

This was the first peacetime test for which the MassComp data acquisition system was available. Because of the availability of the data supplied by the MassComp system, the SCS Automated Decision Aid was available, and it generated the requisite decision aids to the DC Watch Supervisor. At 4 minutes, 10 seconds, the SCS Automated Decision Aid function recommended dispatching the RRT Primary Responders to the Operations Office for a direct attack.

The COTS ionization detector alarmed in the Operations Office at 4 minutes, 39 seconds. Twelve seconds later (4 minutes, 51 seconds), the collocated COTS photoelectric detector alarmed. The RRT Primary Responders reported that they were on-scene at 5 minutes, 22 seconds. At 5 minutes, 48 seconds, personnel were observed to be extinguishing the fire with a portable water extinguisher. At 6 minutes, the RRT Scene Leader reported the fire out in the Operations Office. Personnel in DCC acknowledged the "fire out" report and entered the report into the SCS.

Twenty-seven minutes, 38 seconds after the start of the demonstration, Safety Team members opened the doors to the Radio Transmitter Room (QAWTD 3-24-1) and the starboard passage to induce airflow through the Engineering Storeroom, which was filled with diesel exhaust. At this time, neither the COTS detectors nor the EWFDs on the 3rd Deck alarmed. At 32 minutes, 30 seconds, Safety Team members secured the diesel engine. One minute later, Control Room personnel activated fans E 1-15-1 and E 1-15-2 to ventilate the space. At this time, all performance goals were met and the test was complete.

8.3.3 Use/Effectiveness of DC Systems and Manning

During this demonstration, the EWFD in the Operations Office alarmed 49 and 61 seconds before the COTS ionization and photoelectric detectors alarmed. The RRT Primary Responders were on-scene and extinguishing the fire within 2 minutes of receiving the alarm. The fire was contained to the computer monitor and all test objectives were met. Figure 27 notes the probability of fire as measured by the EWFD in Passage 2-9-0-L. Neither the COTS detectors nor the EWFDs on the 3rd Deck alarmed for the nuisance source (diesel engine exhaust).

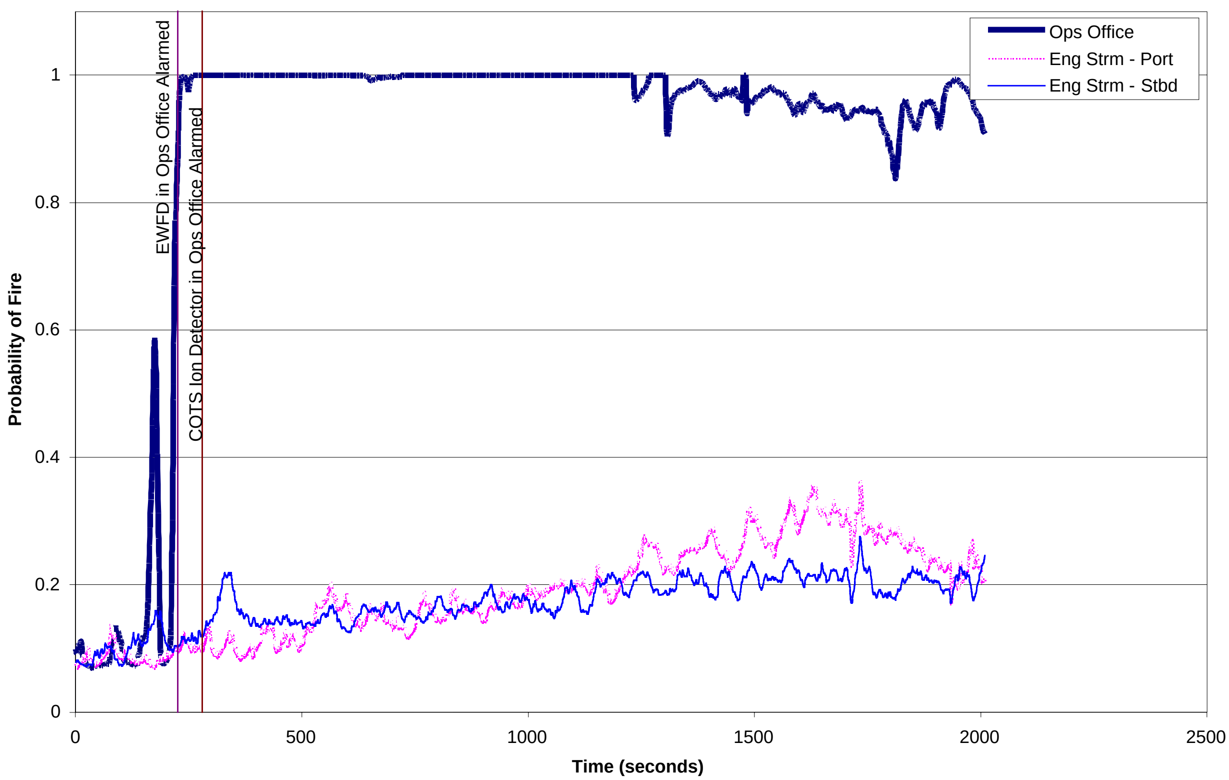


Fig. 27 — Probability of fire, demonstration arm3p03 — smoldering computer monitor (Ops Office) and diesel engine exhaust (Engineering Storeroom)

8.4 Demonstration arm3p04

8.4.1 Test-specific Parameters

The fourth peacetime demonstration included a nuisance source and a smoldering fire. Five pieces of 0.3-m (1-ft) LSDSGU-9 cable were bundled together as the source, located in the Tomahawk Equipment Room. Smoldering was initiated by a heating element (calrod), which was placed between the cables; the variac for the calrod was set at 50 V. The nuisance source consisted of grinding a painted bulkhead in CPO Living.

8.4.2 General Results

The demonstration began when the calrod heater for the electrical cables was energized. Seven seconds later, safety team personnel started grinding the painted surface on the bulkhead in CPO Living. The EWFD located in CPO Living went into alarm 53 seconds after grinding was started (1 minute after the start of the demonstration). At this time, the SCS Compartment Damage Display noted a small fire in CPO Living. Fifteen seconds later, the SCS Surveillance Video displayed a video image of CPO Living in DCC. At 1 minute, 14 seconds, the COTS photoelectric detector alarmed.

The SCS Automated Decision Aid function recommended dispatching the RRT to CPO Living for a direct attack at 1 minute, 18 seconds. The DC Watch Supervisor used the SCS Surveillance Video to confirm that there was no fire in this compartment, and personnel were not sent to the space. Grinding was secured and Control Room personnel activated fan E 1-15-1 to ventilate the space.

Approximately 27 minutes, 30 seconds after the start of the demonstration, the COTS photoelectric detector in the Tomahawk Equipment Room alarmed. A warning was issued by the EWFD in this compartment at 29 minutes, 14 seconds. At 31 minutes, 50 seconds, the COTS photoelectric detector alarmed for a second time. At 37 minutes, 6 seconds, the EWFD system went into alarm. The SCS Compartment Damage Display noted a small fire in the Tomahawk Equipment Room. In addition, the SCS Surveillance Video displayed a video image of the fire compartment, and the SCS Automated Decision Aid function recommended dispatching the RRT to the Tomahawk Equipment Room for a direct attack.

At 37 minutes, 38 seconds, the DC Watch Supervisor called away the fire in the Tomahawk Equipment Room over the 1MC. At this time, the RRT Primary Responders began to make their way to the space. At 39 minutes, 10 seconds, the RRT reported that the fire was out. Personnel in the Control Room secured the test and began to ventilate the space.

8.4.3 Use/Effectiveness of DC Systems and Manning

This demonstration showed how the SCS Surveillance Video and the SCS Compartment Damage Display complement one another to provide good situation awareness. The slow smoldering fire was detected and responded to before transition to a flaming fire. In the case of grinding a painted bulkhead, which produced significant smoke/particulate, the SCS Surveillance Video allowed DCC to identify the alarm as nonthreatening and did not require a response by the RRT. Because of the nature of the overheated smoldering cables, the performance goals for this demonstration were easily met. Figures 28 and 29 show the probability of fire in the test compartments.

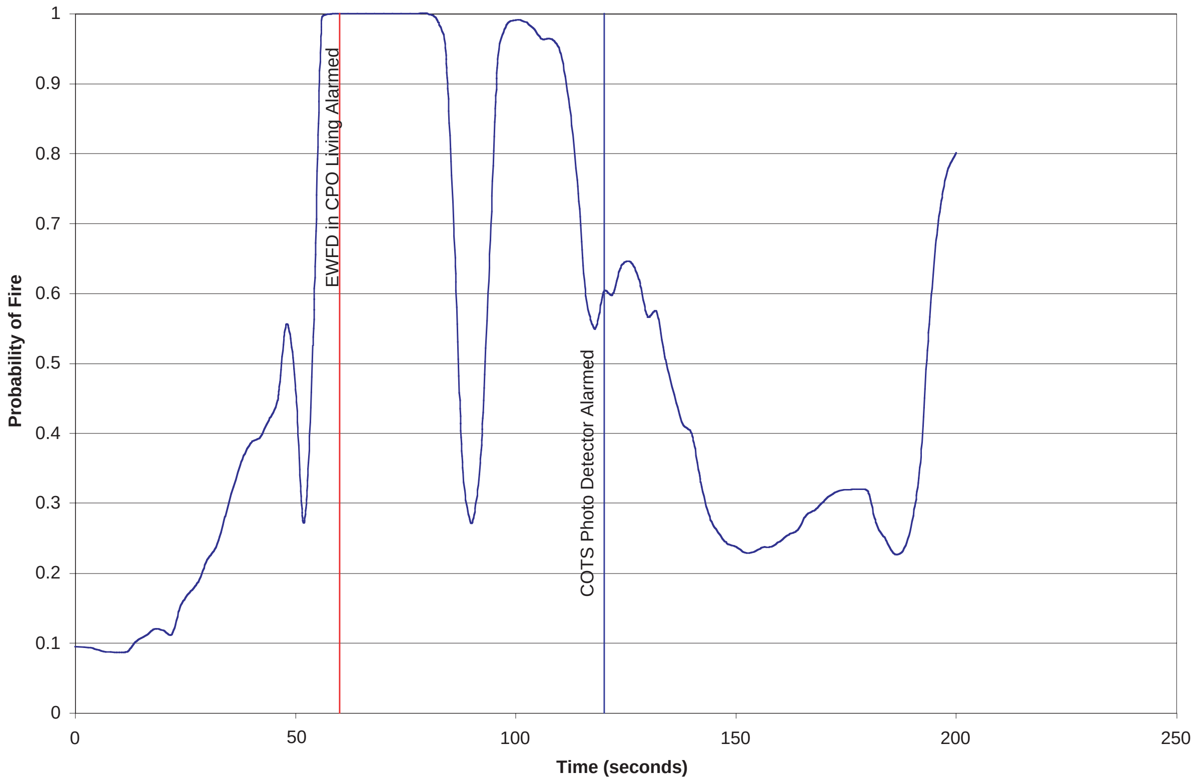


Fig. 28 — Probability of fire, demonstration arm3p04 —grinding steel (CPO Living)

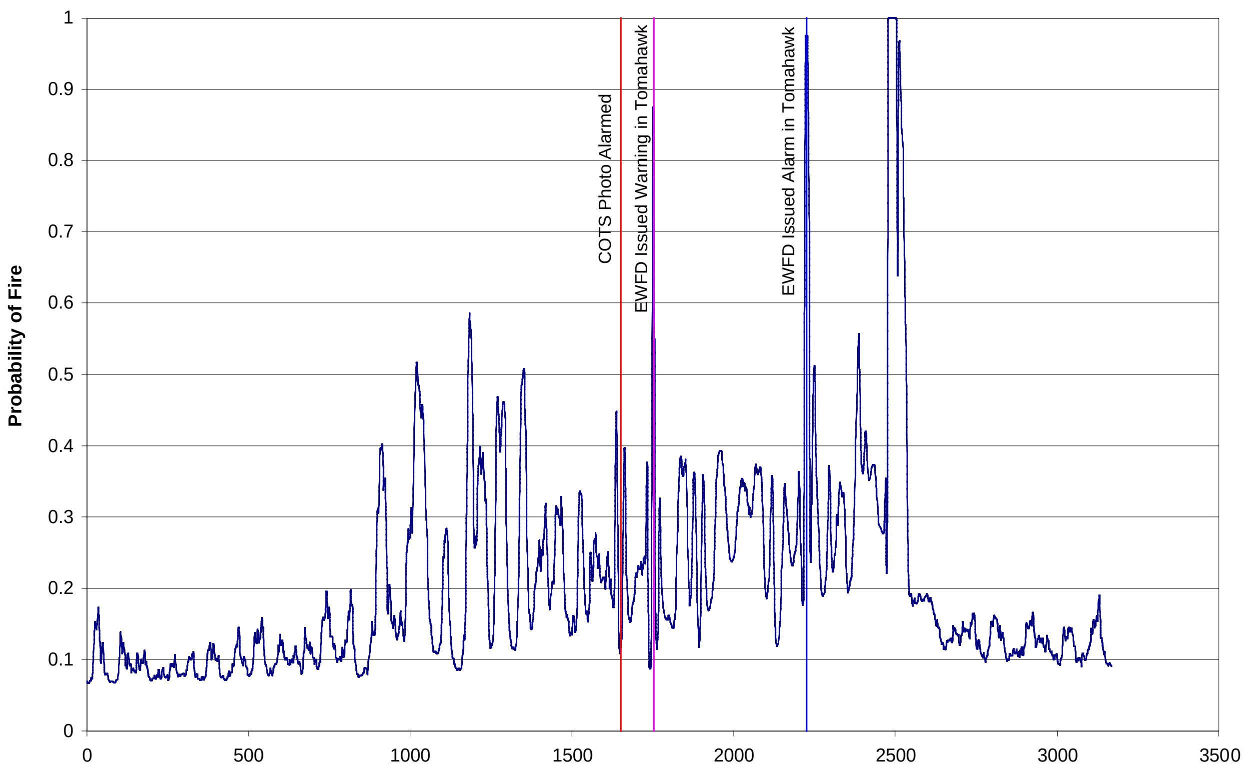


Fig. 29 — Probability of fire, demonstration arm3p04 —smoldering cable (Tomahawk Equipment Room)

8.5 Demonstration arm3p06

8.5.1 Test-specific Parameters

The final peacetime demonstration also included a nuisance source and a smoldering fire. The source for the smoldering fire was a mattress with bedding material in the Operations Office. Smoldering of the bedding materials was initiated by a heating element (calrod), which was placed between the mattress and bedding material. The nuisance source consisted of Safety Team members welding in the Engineering Storeroom.

8.5.2 General Results

The demonstration was started when the calrod heater was energized in the Operations Office. Fifty-five seconds later, Safety Team members began welding in the Engineering Storeroom. At 1 minute, 43 seconds, the starboard early warning detector (EWFD03) probability reached 60%. At this time, the SCS Surveillance Video requested video data from the *Shadwell* LAN. One minute, 59 seconds after the start of the test (1 minute, 4 seconds after welding began), the COTS photoelectric detector in the Engineering Storeroom went into alarm.

At 2 minutes 14 seconds, the SCS Compartment Damage Display noted an alarm from the EWFD system, based on a single probability value above 0.85; EWFD03 actually went into alarm 3 seconds later (when three consecutive probabilities above 0.85 occurred). The DC Watch Supervisor called away a fire in the Engineering Storeroom at 2 minutes, 25 seconds. The DC Watch Supervisor did not have a video image of the compartment because of *Shadwell* LAN time delays. The RRT Primary Responders arrived on-scene at 3 minutes, 43 seconds and reported that there was no fire in the Engineering Storeroom. This information was entered into the SCS by the DCC personnel.

Nine minutes, 27 seconds after the calrod heater was energized in the Operations Office, the SCS Compartment Damage Display received an alarm from the EWFD in the Operations Office, based on a single probability value equal to or above 0.85. At 10 minutes, 57 seconds, the DC Watch Supervisor called away a fire in the Operations Office. The RRT Primary Responders were observed to be on-scene at 11 minutes, 43 seconds. At 12 minutes, 5 seconds, the EWFD sensor in the Operations Office actually went into alarm. Twenty-three seconds later, a report was made that the fire in the Operations Office had been extinguished. At this time, personnel in the Control Room activated fans E 1-15-1 and E 1-15-2 to ventilate the space.

8.5.3 Use/Effectiveness of DC Systems and Manning

For the smoldering scenario, the SCS Compartment Damage Display noted a small fire in the Operations Office based on an EWFD single probability value above 0.85. The early warning detector did not actually go into alarm until three consecutive probability values above 0.85 at 12 minutes, 5 seconds. Figure 30 displays the probability of fire for the Operations Office.

Both the COTS detection system and the EWFD system alarmed for the nuisance source, which was located in the Engineering Storeroom. The COTS photoelectric detector alarmed approximately 20 seconds before the EWFD detector reached its alarm state. The DC Watch Supervisor did not have the SCS Surveillance Video in time to correctly note the error produced by the EWFD system. If the video image had been available, the Rapid Response Team would not have been called away needlessly. Figure 31 shows the probability of fire in the Engineering Storeroom.

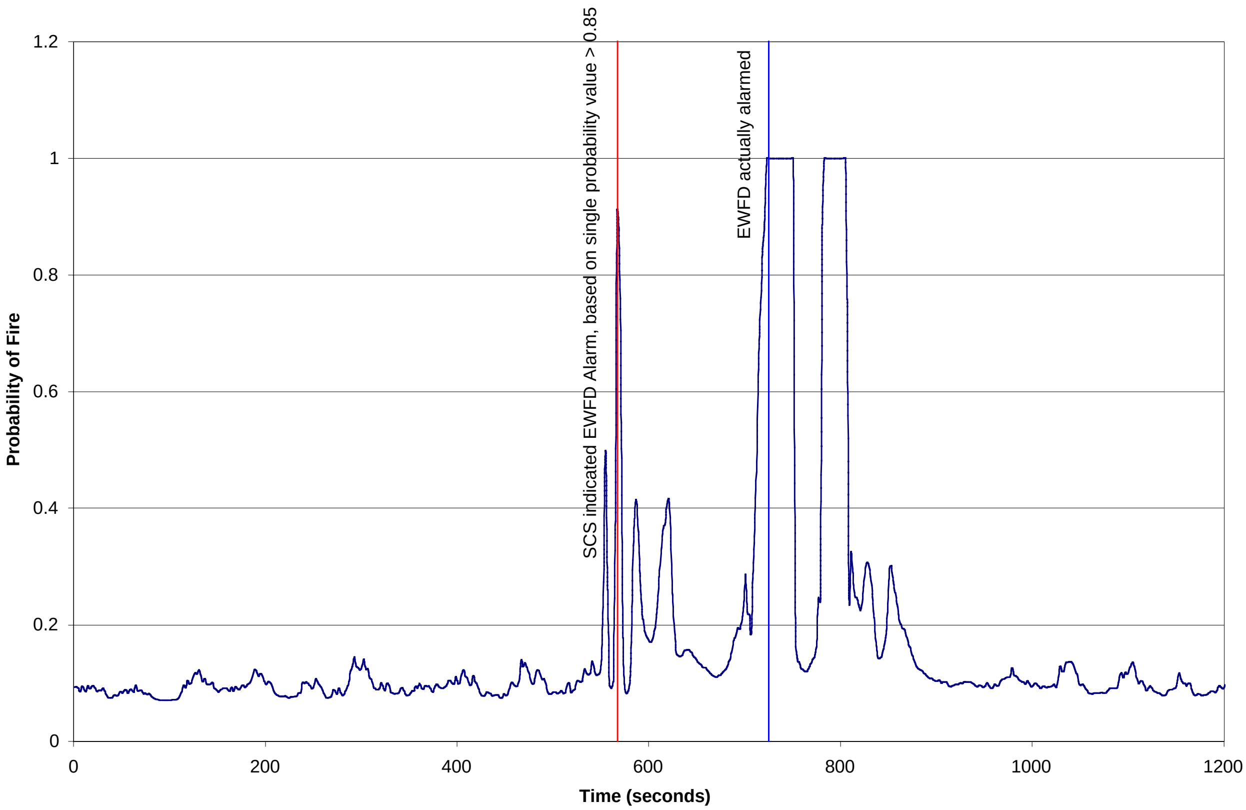


Fig. 30 — Probability of fire, demonstration arm3p06 —smoldering cable (Ops Office)

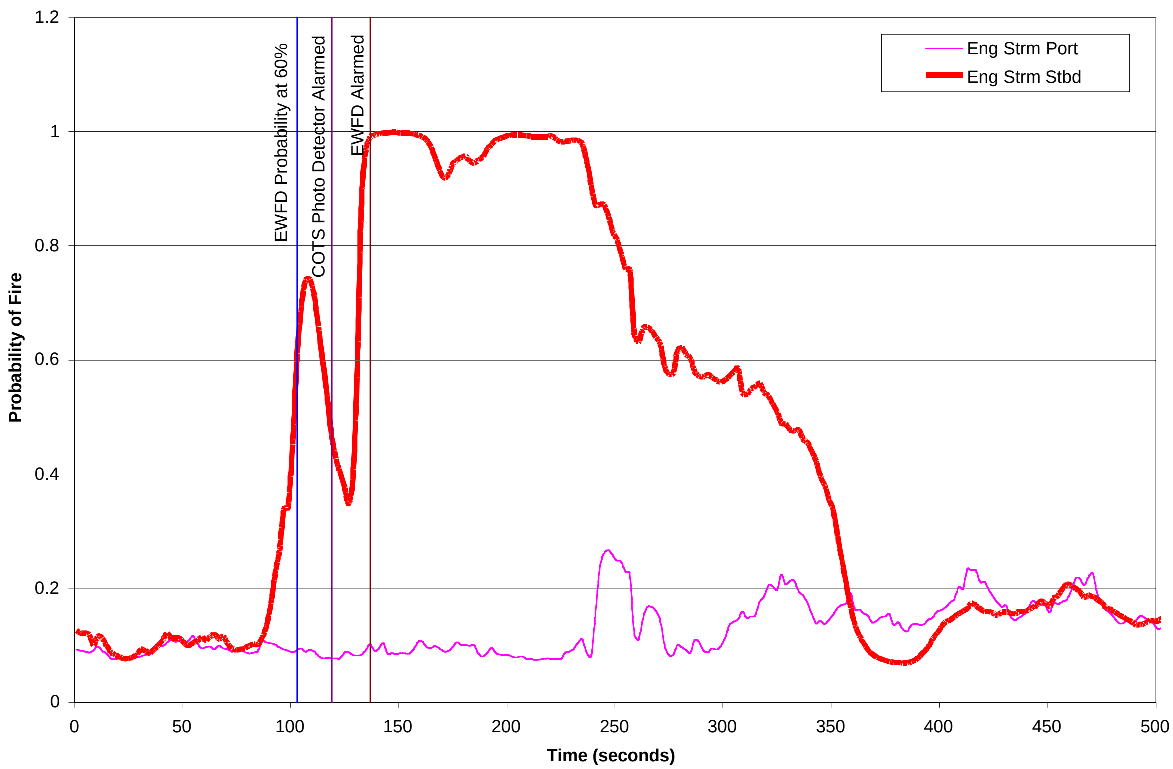


Fig. 31 — Probability of fire, demonstration arm3p06 —welding (Engineering Storeroom)

9. WARTIME DEMONSTRATION RESULTS

Four wartime demonstrations (arm3w05 through arm3w08) were conducted from September 24 to 27, 2001. Table 8 summarizes the wartime demonstration critical events.

The following sections summarize the events that took place during each demonstration. Appendix L provides detailed timelines for each demonstration. Selected instrument data are provided with this discussion. Appendix M provides a more complete set of data.

Table 8 — Summary of Critical Events

Action	arm3w05	arm3w06	arm3w07	arm3w08
Identify PDA	7 s	5 s	19 s	21 s
Time to set boundaries: Automated (water mist) Manually	 14 s 3 min, 14 s	 32 s 3 min, 55 s	 27 s 8 min, 22 s	 27 s 3 min, 39 s
Maintain 20-ft visibility in passageways	Yes	Yes	Yes	Yes
Recovery efforts complete in APDA compartments	29 min	23 min	20 min	28 min
Fire main rupture isolated	1 min, 38 s	N/A[1]	57 s	1 min, 31 s
Machinery space flooding contained	N/A[2]	30 min, 18 s	28 min, 22 s	N/A[2]

[1]Fire main rupture was not initiated during this demonstration.
[2] Main space flooding was not initiated during this demonstration.

9.1 Demonstration arm3w05

9.1.1 Test-specific Parameters

For this demonstration, four compartments adjacent to the primary damage area were selected as sympathetic ignition locations: the Combat System Office, Tomahawk Equipment Room, Engineering Storeroom, and CPO Living. The Combat System Office, Tomahawk Equipment Room, and Engineering Storeroom each contained one bin of fuel. CPO Living contained four bunks with bedding material. The fire main rupture was initiated in the Operations Office.

9.1.2 General Results

The SCS Damage Characterization function identified the PDA within 7 seconds of the simulated missile hit. Fully involved fires were noted by the SCS Compartment Damage Display in the Comm Center, CIC, Radio Transmitter Room, and Crew Living. The DCO reviewed the damaged areas with the investigation teams and directed the investigation of the damage area.

The SCS Water Mist Control function began automatically setting fire boundaries by activating the water mist system in BC mode (i.e., setting system to "ready" mode) in the APDA compartments (i.e.,

CSMC/Repair 8, Tomahawk Equipment Room, Engineering Storeroom, Combat System Office, and Operations Office) 14 seconds after the missile hit. At 16 seconds, the Safety Team ignited the wood crib fuel pan in the Radio Transmitter Room. At 38 seconds, the SCS Automated Decision Aid function recommended dispatching a Support Team to set manual fire boundaries on the 2nd Deck passageways, where water mist was not available. Based on this decision aid, the DCO ordered manual fire boundaries on the 2nd Deck.

At 1 minute, 9 seconds, Control Room personnel initiated the Operations Office fire main rupture. The SCS Fire Main Control function detected a potential fire main rupture within 19 seconds and began to automatically close valves to isolate the rupture. One minute, 19 seconds later, the SCS Automated Decision Aid function noted that the rupture had been isolated and which fire plugs were out of service.

Temperatures in CPO Living began to rise after the missile hit. The temperature rise was due to heating of the deck and aft bulkhead, which were adjacent to the PDA. At this time, sympathetic ignition of the combustibles in CPO Living had not occurred; temperatures in the compartment were approximately 68°C (155°F). Based on the increasing temperatures in the compartment, the SCS Compartment Damage Display function noted a medium fire in CPO Living and energized the water mist system in BC mode at 1 minute, 39 seconds. The SCS Water Mist Control function activated the BC mode since the compartment temperatures exceeded 60°C (140°F), the threshold at which water mist is energized in BC mode. While in BC mode, water mist was energized and de-energized on a timed cycle, in which water flowed approximately 33% of the time. SCS Surveillance Video was not used in CPO Living because of poor visibility.

One and a half minutes after the missile hit, Safety Team personnel ignited the fire in AMR No. 1. At 2 minutes, 40 seconds, the SCS Compartment Damage Display noted a medium fire in this compartment based on temperature measurements. One minute, 46 seconds after the fire in AMR No. 1 was detected, the DCO sent Investigation Team #1 to check the space for possible fires. Based on the detected fire in AMR No. 1, the DCO ordered an additional manual fire boundary in the Engineering Operations Station. At 13 minutes, 1 seconds, the Repair 2 Casualty Coordinator reported that this boundary had been set.

Three minutes, 12 seconds after the start of the demonstration, the SCS Automated Decision Aid function recommended dispatching the Attack Team to CSMC/Repair 8 to perform an indirect attack on the fire in CIC. Two seconds later, the Repair 2 Casualty Coordinator reported that manual fire boundaries were set on the 2nd Deck. The SCS Automated Decision Aid function generated a recommendation to dispatching an Attack Team to conduct a direct attack of the fire in the Comm Center at 3 minutes, 40 seconds.

Approximately 8 minutes into the demonstration, Investigation Team #2 reported that CPO Living was clear. At 8 minutes, 14 seconds, the DCO ordered the investigators to confirm the fire in CIC. A fire in Combat System Office was reported by the investigators at 8 minutes 48 seconds; sympathetic ignition had occurred in this space. At 11 minutes, 19 seconds, the SCS Compartment Damage Display noted smoke in Passage 2-15-3-L. The SCS Automated Decision Aid function recommended that the DCO activate the SES. Twenty-two seconds later, the SES was activated by the DCO. Within 25 seconds, visibility began to increase in the passageway and the SCS reported that the passage was clear of smoke.

Twelve minutes, 45 seconds after the missile hit, the DCO reported that the fires appeared to have been contained; fire boundaries were set on the 2nd Deck and were in the process of being set on the 3rd Deck. Based on these observations, the DCO ordered Repair 2 to conduct an indirect fire attack in CIC. The DCO also ordered Repair 2 to conduct a direct fire attack in AMR No. 1.

At 13 minutes, 3 seconds, a fully involved fire was noted by the SCS Compartment Damage Display in the port passageway outside of CSMC/Repair 8 (Passage 1-15-4-L). The SCS Automated Decision Aid

function recommended dispatching an Attack Team to set manual fire boundaries around this space. Investigation Team #2 was sent to this space to check for possible fire. Approximately 5 minutes, 30 seconds later, the investigators reported that there was no fire in Passage 1-15-4-L. This false fire indication was due to a transient signal spike in the thermocouple sensor monitoring the 1-15-4-L passageway.

A report was made that the door to the Engineering Storeroom (QAWTD 3-25-0) was hot by Investigation Team #1, at 16 minutes, 20 seconds. Based on this report, DCC incorrectly updated the SCS to reflect a fire in this space. The SCS Compartment Damage Display still noted a fire in CPO Living, since no reports had been made to confirm the condition of the space. The DCO attempted to direct Investigation Team #1 to CPO Living to check for possible fire. DCC was not able to communicate with Investigation Team #1 because of Communication problems. The DCO then directed Investigation Team #2 to investigate CPO Living.

The indirect attack of CIC was started approximately 16 minutes, 30 seconds after the start of the test. At 17 minutes, 54 seconds, the Repair 2 Casualty Coordinator reported that the indirect attack of CIC, and the direct attack of AMR No. 1 were still in progress. The indirect attack was reported complete approximately 3 minutes after it had been started. Based on the completion of the indirect attack, the DCO ordered a direct attack of the fire in the Comm Center approximately 22 minutes, 30 seconds after the start of the demonstration. At 25 minutes, the Repair 2 Casualty Coordinator reported that the Attack Team was en route to the Comm Center.

A fire was incorrectly reported in the Operations Office by the investigators at 25 minutes, 18 seconds. The investigators reported that they were cooling the Operations Office bulkhead from the Combat System Office. At 27 minutes, 30 seconds, Investigation Team #2 reported that the Operations Office was clear. The investigators also reported that the Engineering Storeroom and CSMC/Repair 8 were clear.

Approximately 29 minutes after the initial missile hit, indirect cooling of CIC was restarted. At 29 minutes, 10 seconds, Investigation Team #1 reported that the Tomahawk Equipment Room was hot, but appeared to be cooling. At this time, DCC incorrectly entered a fire in this compartment into the SCS. As discussed in Section 4.13, the EWFD is the only means to identify a small fire by the SCS Compartment Damage Display. The EWFD system was not used during the wartime demonstrations. The fire was later cleared by the DCO.

At 30 minutes, 12 seconds, the fire in AMR No. 1 was reported out and a reflash watch was set. Approximately 1 minute later, Investigation Team #1 reported that MMR No. 1 was clear. The Repair 2 Casualty Coordinator reported that there was no fire, but there was a lot of heat in CIC. At 34 minutes, 47 seconds, Repair 2 reported that the Attack Team was accessing the Comm Center. A direct attack on the fire was started approximately 1 minute later. Thirty-seven minutes, 31 seconds after the initial missile hit, the Repair 2 Casualty Coordinator reported that the fire in the Comm Center was out and that the reflash watch was set.

Investigation Team #1 was sent to confirm the status of fire in CIC at 38 minutes, 26 seconds. At 38 minutes, 34 seconds, the fire in the Comm Center was reported to have reflashed. Approximately 1 minute later, the Repair 2 Casualty Coordinator reported that the reflash fire in the Comm Center was out. The investigators reported that the door to CIC was hot and requested permission to cool the door in order to try to access the space. The DCO ordered Repair 2 to confirm the status of fire in the Radio Transmitter Room and Crew Living. All fires were confirmed out and the demonstration was complete.

9.1.3 Identification of the Fires/Water Mist System Operation

Immediately after the missile hit, fully involved fires were identified by the SCS Damage Characterization function in the Comm Center, CIC, Radio Transmitter Room, and Crew Living based on damaged sensor data and the predicted damage area. One and a half minutes after the missile hit, Safety Team personnel ignited the F76 pan fire in AMR No. 1. One minute, 10 seconds later, the SCS Compartment Damage Display noted a medium fire in this compartment. Although four out of the six sensors in AMR No. 1 were damaged, two sensors were still available, enabling the SCS to detect a medium fire in this compartment.

At 1 minute, 39 seconds, the SCS Compartment Damage Display incorrectly noted a medium fire in CPO Living and activated the water mist system in BC mode. The temperature in this compartment was approximately 68°C (155°F). Although water mist had been energized, temperatures in the compartment continued to increase slightly because the system was cycling on and off in BC mode. At 7 minutes, 27 seconds, the SCS Water Mist Control function switched the water mist system to the modified FS mode; at this time, the compartment temperature was approximately 78°C (173°F). The investigators reported that this space was clear (i.e., no fire) approximately 30 seconds later. The CPO Living space is immediately over and adjacent to the PDA fires and has numerous cracks in the deck due to repeated fire exposure. These openings also contributed to smoke migration into CPO Living, which limited the effectiveness of the SCS Surveillance Video. For these reasons, the CPO Living space poses a difficult challenge for the SCS system to distinguish between real and false fire events.

A fire in Combat System Office was observed and reported by the investigators at 8 minutes, 48 seconds. This information was input into the SCS by DCC personnel, and a small fire was noted on the SCS Compartment Damage Display. At the time the fire was reported by the investigators, the compartment temperature was less than 50°C (122°F). At 26 minutes, 11 seconds, the compartment was reported to be clear. A fire was incorrectly reported in the Operations Office by the investigators at 25 minutes, 18 seconds. DCC personnel updated the SCS to reflect a fire in this compartment. Temperatures in the compartment remained well below 65°C (150°F), and water mist was not energized in this space. At 27 minutes, 30 seconds, the investigators reported that the Operations Office was clear.

At 16 minutes, 20 seconds, the investigators reported that the door (QAWTD 3-25-0) to the Engineering Storeroom was hot. Based on this report, DCC personnel incorrectly updated the SCS to reflect a fire in this space. Temperatures in this space were approximately 60°C (140°F); a fire had not occurred in this compartment. Approximately 29 minutes after the missile hit, Investigation Team #1 reported that the Tomahawk Equipment Room was hot. DCC personnel again incorrectly input a fire in this compartment into the SCS. The water mist system was energized in BC mode approximately 22 minutes, 30 seconds after the start of the test in both the Engineering Storeroom and the Tomahawk Equipment Room. A report was made that the Engineering Storeroom was clear at 28 minutes, 6 seconds, and the SCS was updated to reflect this report. At 28 minutes, 30 seconds, the DCO cleared the fire from the Engineering Storeroom, as he realized that there was no fire in this compartment.

At 13 minutes, the SCS Compartment Damage Display incorrectly noted a fully involved fire in the port passageway outside of CSMC/Repair 8 (Passage 1-15-4-L). The investigation team was sent to check the passageway for fire at 15 minutes, 44 seconds. Approximately 3 minutes later, personnel reported that there was no fire in this space. The false fire indication was due to a transient signal spike in the thermocouple sensor that monitored the 1-15-4-L passageway.

9.1.4 Fire Main Rupture

At 1 minute, 9 seconds, Control Room personnel initiated the Operations Office fire main rupture. The SCS Fire Main Control function detected a potential fire main rupture within 19 seconds, and began to automatically close valves to isolate the rupture. One minute, 19 seconds later, the SCS Automated Decision Aid function noted that the rupture had been isolated.

9.1.5 Fire Boundaries

Within 14 seconds of the missile hit, the SCS Water Mist Control function automatically set fire boundaries by activating the water mist system in BC mode in the APDA compartments. The SCS Automated Decision Aid function recommended dispatching the Support Team to set manual fire boundaries in areas where water mist was not available. Based on this recommendation, the DCO ordered manual fire boundaries on the 2nd Deck passageways.

Manual boundaries were also recommended in the area around Passage 1-15-4-L because of the detected fire in this space. The DCO waited until the space had been investigated before requesting manual fire boundaries. The investigators reported that there was no fire in Passageway 1-15-4-L; the recommended boundaries were not necessary.

9.1.6 Compartment Temperature Profiles

Before the indirect attack of CIC was started, overhead temperatures in the Comm Center exceeded 500°C (932°F) and temperatures in CIC reached approximately 230°C (446°F). Indirect cooling of CIC from CSMC/Repair 8 was started approximately 16 minutes, 30 seconds after the missile hit. The overhead temperatures in CSMC/Repair 8 increased by approximately 20°C (68°F) when the indirect attack was started. However, temperatures in this compartment were tenable and remained below 60°C (140°F) while the indirect attack was conducted.

Temperatures in the Comm Center and CIC immediately decreased after the indirect attack was started. The temperatures in the Comm Center dropped below 300°C (572°F), and temperatures in CIC remained less than 150°C (302°F). The indirect attack was secured at 21 minutes, and the direct attack of AMR No. 1 was started. Prior to this time, temperatures in AMR No. 1 exceeded 300°C (572°F). Once the direct attack was started, the compartment temperatures in AMR No. 1 dropped to approximately 150°C (302°F). At 29 minutes, indirect cooling of CIC was restarted, while the Support Team provided access to the Comm Center (one deck below CIC). When the indirect attack was restarted, temperatures in the Comm Center, CIC, and AMR No. 1 decreased (Figs. 32 through 34). The direct attack of the fire in the Comm Center was started approximately 36 minutes after the missile hit. The direct attack of the fire in the Comm Center provided additional cooling in this compartment.

Temperatures in the APDA spaces remained relatively low for the entire test. At 8 minutes, 48 seconds, the investigators reported a fire in the Combat System Office. At this time, temperatures in this space were below 45°C (113°F). Water mist was not activated in this space and the compartment temperatures generally remained below 50°C (122°F).

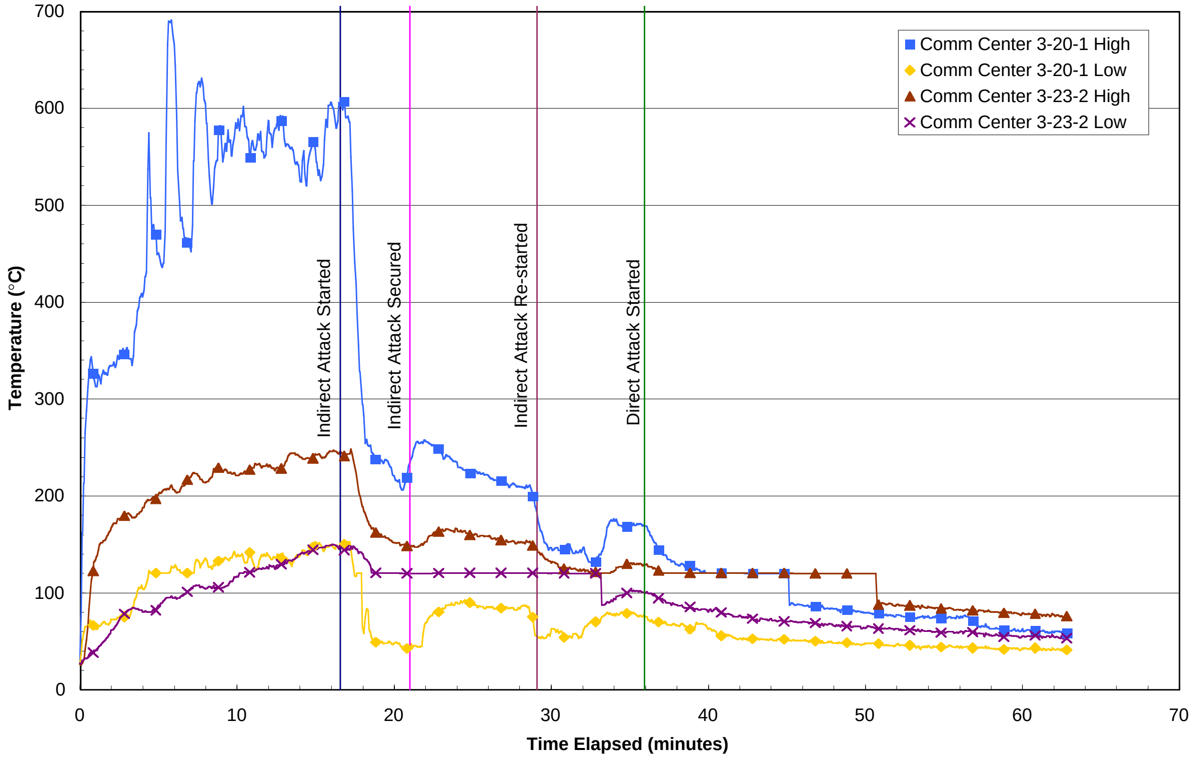


Fig. 32 — Temperatures in the Comm Center, demonstration arm3w05

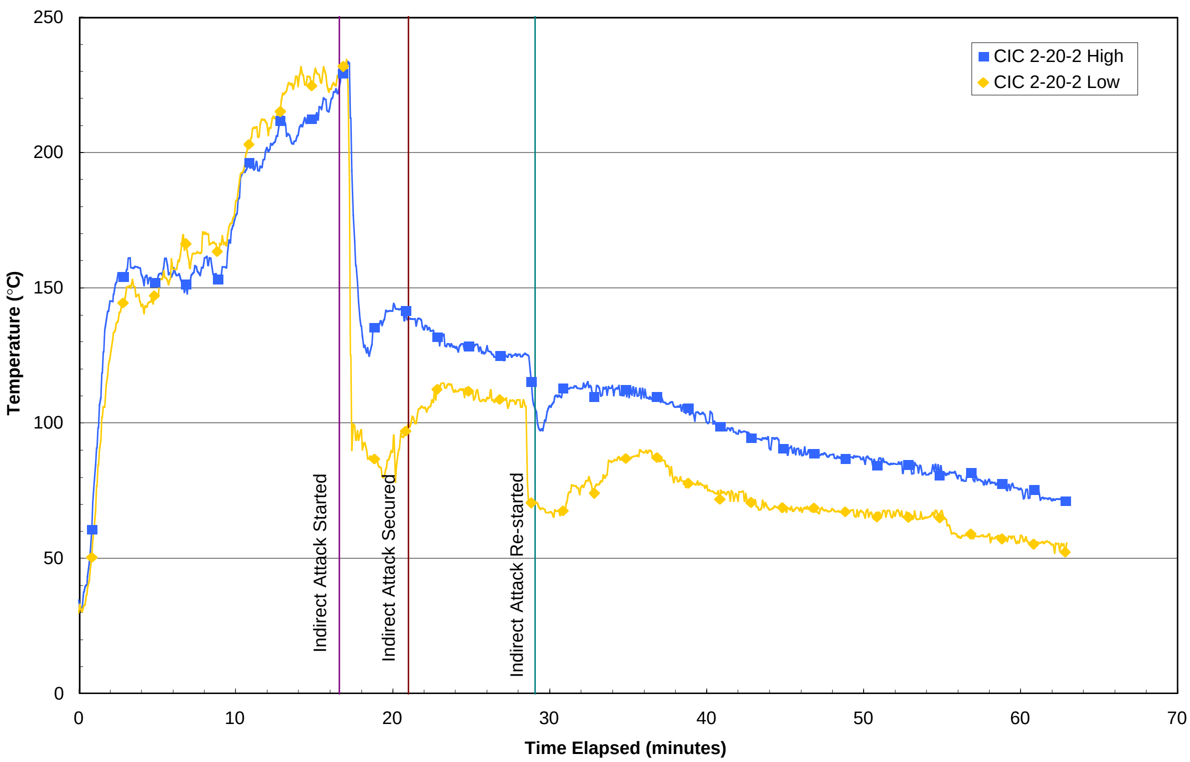


Fig. 33 — Temperatures in the CIC, demonstration arm3w05

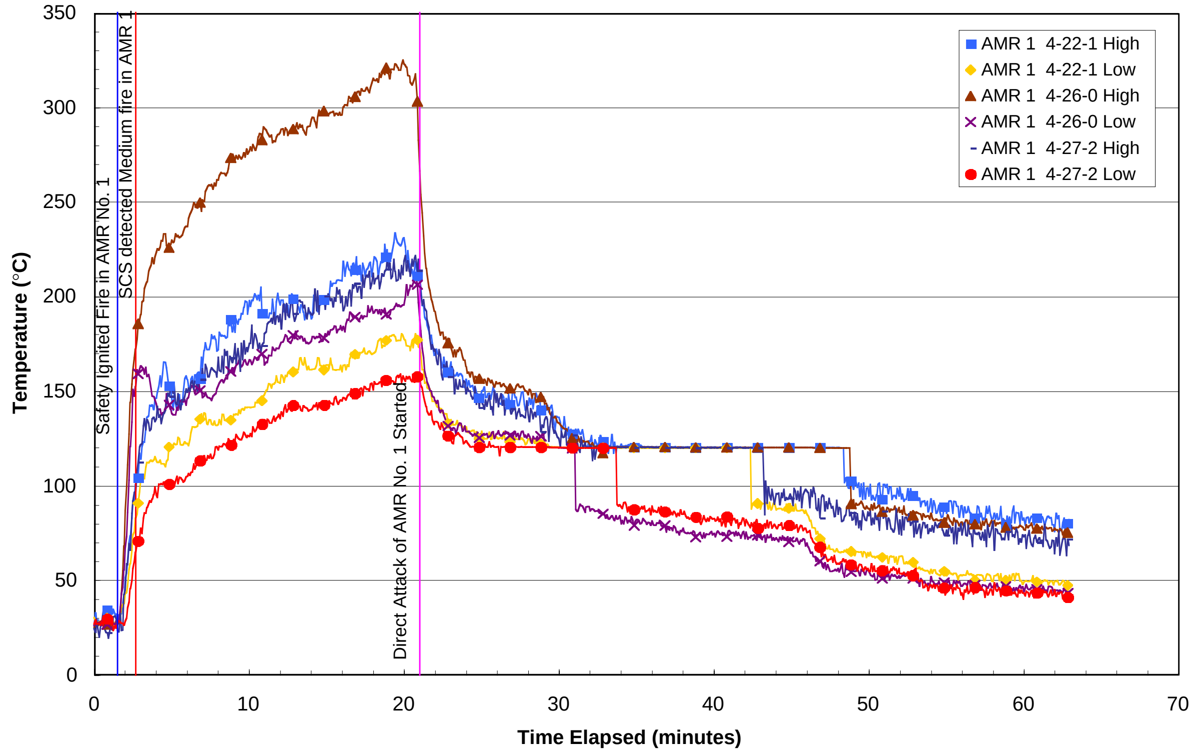


Fig. 34 — Temperatures in AMR No. 1, demonstration arm3w05

Approximately 1 minute, 30 seconds after the start of the test, a medium fire was detected in CPO Living and water mist was activated. At this time, temperatures in the compartment were approximately 68°C (155°F). Temperatures in the compartment decreased/increased as the water mist system was energized and de-energized, respectively. Temperatures in the Engineering Storeroom and the Tomahawk Equipment Room remained below 60°C (140°F) throughout the test.

9.1.7 Smoke Control Effectiveness

Smoke was detected by the SCS in Passage 2-15-3-L, 11 minutes, 19 seconds after the demonstration was started. Within 5 seconds, the SCS Automated Decision Aid function recommended activating the SES. The SES was activated by the DCO, and the SCS noted that the smoke had cleared the passageway at 12 minutes, 6 seconds (Fig. 35). At 20 minutes, 23 seconds, smoke was again detected in Passage 2-15-3-L by the SCS. At approximately the same time, test team members secured fan E 1-15-1, which was being used to help ventilate the fires. Approximately 1 minute later, fan E 1-15-2 was secured. SCS reported that smoke immediately began to clear from the passageways.

9.2 Demonstration arm3w06

9.2.1 Test-specific Parameters

For demonstration arm3w06, the Tomahawk Equipment Room, Combat System Office, Engineering Storeroom, and CPO Living were selected for sympathetic ignition locations. The Combat System Office, Tomahawk Equipment Room, and Engineering Storeroom each contained one bin of fuel, while CPO Living contained four bunks with bedding material. Progressive flooding was included in MMR No. 1. A fire main rupture was not initiated in this evolution.

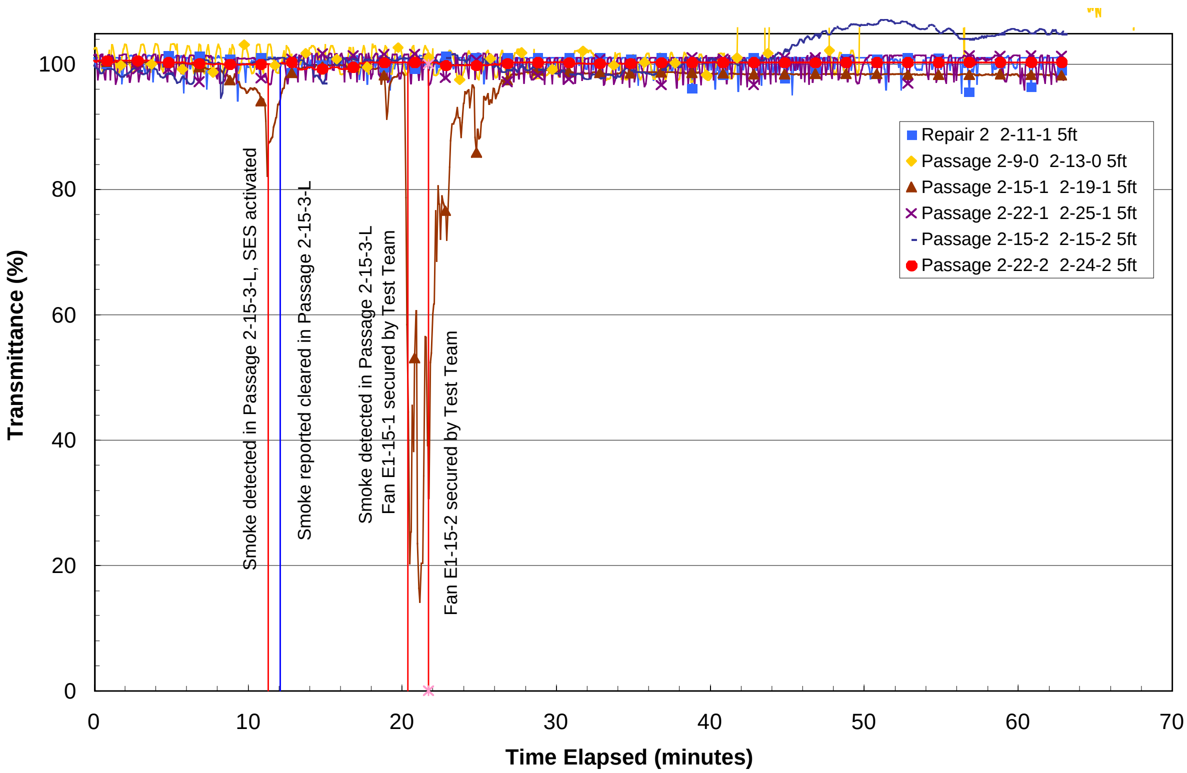


Fig. 35 — Smoke density on the Second Deck, demonstration arm3w05

9.2.2 General Results

The SCS Casualty Characterization function identified most of the PDA within 5 seconds of the simulated missile hit. Fully involved fires were noted by the SCS Compartment Damage Display function in the Comm Center, Radio Transmitter Room, Crew Living, and Tomahawk Equipment Room Vestibule. At 7 seconds, the SCS Compartment Damage Display function noted CPO Living as an APDA compartment and activated the water mist system in BC mode. Twenty-three seconds after the missile hit, the SCS Compartment Damage Display function noted a fully involved fire in CIC. The DCO reviewed the damaged areas with the BDAT and directed an investigation of the damage area.

The SCS Water Mist Control function set fire boundaries by activating the water mist system in BC mode in the remaining APDA compartments, approximately 32 seconds after the missile hit. At 58 seconds, the SCS Automated Decision Aid function recommended setting manual fire boundaries on the 2nd Deck, where water mist was not available. At this time, the DCO ordered manual fire boundaries on the port and starboard sides on the 2nd Deck. Three minutes, 55 seconds after the missile hit, the Casualty Coordinator reported that manual fire boundaries were set.

At 2 minutes, 25 seconds, the SCS Compartment Damage Display noted a medium fire in CPO Living. Nine seconds later, SCS Water Mist Control function energized the water mist system for CPO Living in BC mode because of the elevated temperatures in the compartment. Approximately 4 minutes after the missile hit, the SCS Water Mist Control function energized water mist in BC mode in the Tomahawk Equipment Room. Three seconds later, the SCS Compartment Damage Display function noted a large fire in this compartment. At 4 minutes, 43 seconds, the DCO sent Investigation Team #2 to check the Tomahawk Equipment Room for fire.

The investigators continued performing routine investigations of the damaged areas. At 6 minutes, 7 seconds, the DCO sent investigators to verify whether there was a fire in the Tomahawk Equipment Room Vestibule. One minute, 23 seconds later, the investigators reported that there was no fire in this space.

Seven minutes, 13 seconds after the initial damage, Investigation Team #1 reported that the door to AMR No. 1 was jammed and cool. The investigators reported that they were attempting to access AMR No. 1 at 9 minutes, 22 seconds. One minute, 27 seconds later, Investigation Team #1 reported that the escape trunk in AMR No. 1 was flooded. This information was passed to the Casualty Coordinator. At 12 minutes, 18 seconds, an Attack Team was sent to AMR No. 1 to contain flooding.

Approximately 14 minutes after the initial damage, Investigation Team #2 reported that the forward bulkhead in CPO Living was hot, but there was no fire in the compartment. At 15 minutes, 13 seconds, water mist in the Tomahawk Equipment Room was secured, based on a request made by on-scene personnel. Investigators reported that there was no fire in the Tomahawk Equipment Room. The indirect attack of CIC was started approximately 13.5 minutes after the initial missile hit. At 18 minutes, 3 seconds, on-scene personnel reported that there was no fire in CIC; however, personnel confirmed fire in the Comm Center.

Sympathetic ignition of the bin in the Combat System Office occurred approximately 20 minutes after the start of the demonstration. This fire was first noticed by the DCO using the SCS Surveillance Video system. The investigators were sent to verify the status of the fire in this space. At 22 minutes, 46 seconds, the investigators confirmed that there was a small fire in Combat System Office; 14 seconds later the investigators reported that the fire had been extinguished.

At 21 minutes, 27 seconds, the DCO directed the Attack Team to perform a direct attack on the fire in the Comm Center. The DCO also noted that forcible entry would be required to the Comm Center since all the accesses to the Comm Center were hot and jammed. Approximately 2 minutes later, the Casualty Coordinator reported that the Support Team was en route to provide access to the Comm Center. At 27 minutes, 16 seconds, the Casualty Coordinator reported that access to the Comm Center was made. Twenty-nine minutes, 34 seconds after the start of the demonstration, a Class A fire in the Comm Center and the initiation of the direct attack were reported.

Thirty minutes, 18 seconds into the demonstration, the Casualty Coordinator reported that plugging repair was complete and progressive flooding had been stopped in MMR No. 1. The investigators continued their investigations of the spaces. Reports were made that there were no fires in the Engineering Storeroom and Tomahawk Equipment Room. At 39 minutes, 6 seconds, the Repair 2 Casualty Coordinator reported that the fire in the Comm Center had been extinguished. At this time, all fires had been extinguished and the demonstration was complete.

9.2.3 Identification of the Fires/Water Mist System Operation

Based on loss of data and predicted damage areas, the SCS Casualty Characterization function identified fully involved fires in Crew Living, Comm Center, Radio Transmitter Room, Tomahawk Equipment Room Vestibule, and CIC. All areas were correctly identified except the Tomahawk Equipment Room Vestibule, which had faulty sensor data. Temperatures in CPO Living quickly increased after the fires in the PDA were ignited. Based on the increasing temperatures, a medium fire was identified in CPO Living, approximately 2 minutes, 30 seconds after the missile hit. At this time, the temperature in the compartment was approximately 82°C (180°F). Within 10 seconds, the water mist system was energized in BC mode. At 3 minutes 50 seconds, water mist was switched to modified FS mode. Approximately 14 minutes, 30 seconds after the demonstration was started, the investigators reported that there was no fire in CPO Living.

The CPO Living space is immediately over and adjacent to the PDA fires and has numerous cracks in the deck due to repeated fire exposure. These openings also contributed to smoke migration into CPO Living, which limited the effectiveness of the SCS Surveillance Video. For these reasons, the CPO Living space poses a difficult challenge for the SCS system to distinguish between real and false fire events.

Sympathetic ignition of the bin in the Tomahawk Equipment Room occurred at 3 minutes, 25 seconds. Within 38 seconds, the SCS Water Mist Control function activated the water mist system, and the SCS Compartment Damage Display function noted a large fire in the space. At this time, temperatures in the compartment exceeded 225°C (437°F). At 4 minutes, 41 seconds, the water mist system was switched to modified FS mode and an investigation team was sent to determine the status of the fire. Water mist worked well to extinguish the fire and cool the compartment temperatures, which quickly decreased and remained below 50°C (122°F). At 15 minutes, 13 seconds, water mist was secured at the request of on-scene personnel. The investigators reported that there was no fire in the compartment.

At the start of the demonstration, the SCS Casualty Characterization function incorrectly included the Tomahawk Equipment Room Vestibule as part of the PDA. This was because of the induced sensor damage that was activated at the onset of the missile hit. An investigation team was sent to check this compartment for fire at 6 minutes, 7 seconds. SCS Surveillance video was not available in this compartment. Approximately 1-1/2 minutes later, a report was made that there was no fire in this space.

Sympathetic ignition of the bin in Combat System Office occurred approximately 20 minutes after the initial damage. This fire was noted by the DCO using the SCS Surveillance Video. Temperatures in the space exceeded 75°C (167°F); however, water mist was never energized. Investigators were sent to the space to verify the status of the fire. At 22 minutes, 46 seconds, the investigators reported a small fire in Combat System Office. An additional report was made 14 seconds later that the fire had been extinguished. The DCO completed all recovery actions in the APDA compartments within 23 minutes of the missile hit.

9.2.4 Fire Boundaries

Immediately after the fires in the PDA were identified, the SCS Water Mist Control function engaged the water mist in the BC mode within the APDA compartments. By activating water mist in BC mode, fire boundaries were automatically set in areas where water mist was available. At 58 seconds, the SCS Decision Aid function recommended setting manual fire boundaries in the passageways on the 2nd Deck, where water mist was not available. At this time, the DCO ordered manual fire boundaries on the 2nd Deck, port and starboard sides.

The SCS Compartment Damage Display function incorrectly noted a fire in CPO Living, approximately 2 minutes, 25 seconds after the start of the demonstration. Based on a fire in this location, an additional manual boundary was incorrectly directed on the 2nd Deck, forward of this space. At 2 minutes, 56 seconds, the DCO ordered an additional manual fire boundary, forward of CPO Living. At 3 minutes, 55 seconds, the Casualty Coordinator reported that the manual fire boundaries were set on the 2nd Deck. This additional fire boundary was not required because there was a functional water mist system in the primary fire compartment.

At 12 minutes, 32 seconds, the DCO again incorrectly ordered a manual fire boundary in the Engineering Storeroom. Although the temperatures in the Engineering Storeroom were relatively low (below 50°C (122°F)), the SCS was receiving faulty data for the Engineering Storeroom sensors. Actual compartment temperatures were not available to the SCS or DCC personnel. DCC personnel attempted to energize water

mist in this compartment; however, the SCS did not respond to these actions. It is not apparent why the SCS did not respond to the DCO's request to energize water mist in this space.

9.2.5 Compartment Temperature Profiles

The overhead temperatures in the Comm Center slightly exceeded 600°C (1112°F) and temperatures in CIC exceeded 230°C (446°F) before the indirect attack was started (Fig. 36). Indirect cooling of CIC from CSMC/Repair 8 was started approximately 13 minutes, 30 seconds after the initial missile hit. Temperatures in CSMC/Repair 8 slightly increased when the indirect attack was started. However, compartment temperatures stayed below 50°C (122°F) for the duration of the demonstration.

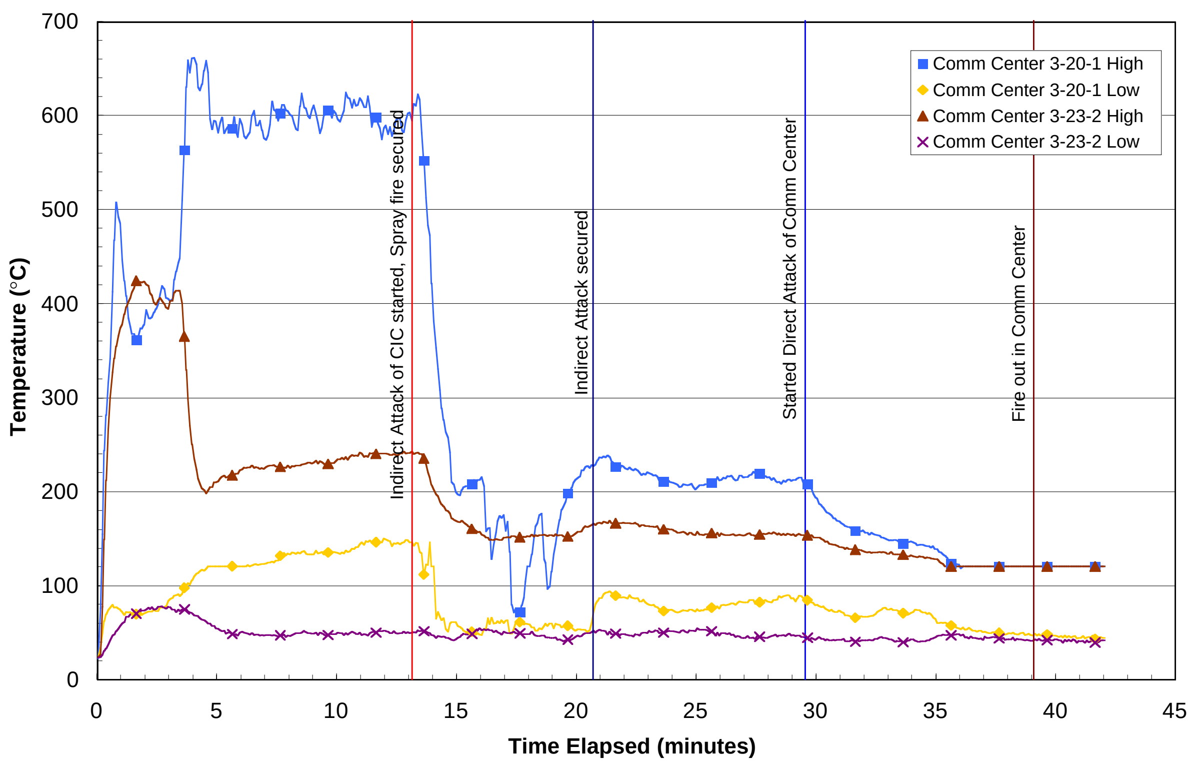


Fig. 36 — Temperatures in the Comm Center, demonstration arm3w06

When the indirect attack was started, temperatures in the Comm Center and CIC immediately decreased. Temperatures in the Comm Center dropped below 250°C (482°F), while temperatures in CIC decreased to 150°C (302°F). At 20 minutes, 43 seconds, the indirect attack was secured. The direct attack of the fire in the Comm Center was started approximately 29 minutes, 30 seconds after the missile hit. The direct attack provided additional cooling of the Comm Center, enabling the temperatures to be reduced below 150°C (302°F).

Sympathetic ignition of the bin in the Tomahawk Equipment Room occurred approximately 3 minutes, 30 seconds after the start of the test. Compartment temperatures peaked at approximately 230°C (446°F). The water mist system, which was engaged in modified FS mode, quickly extinguished the fire and effectively maintained compartment temperatures around 50°C (122°F) (Fig. 37).

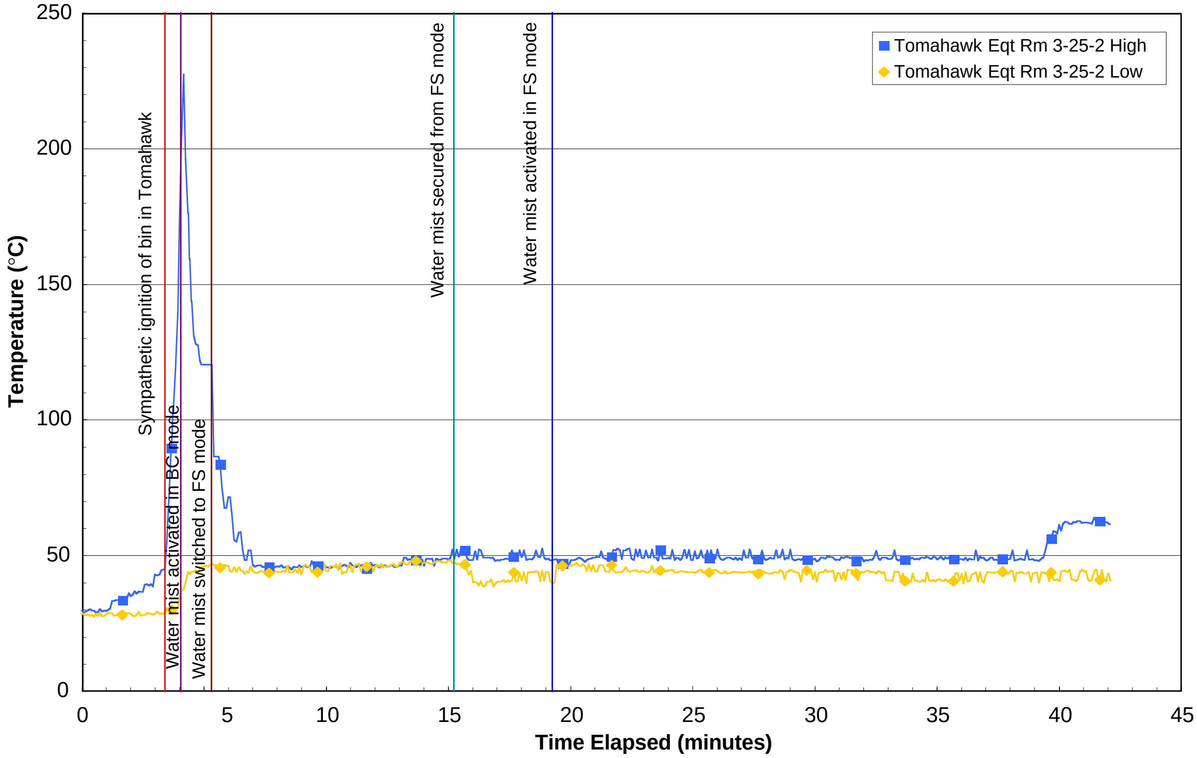


Fig. 37 — Temperatures in the Tomahawk Equipment Room, demonstration arm3w06

The bin in the Combat System Office ignited approximately 20 minutes after the missile hit. Although temperatures in the compartment exceeded 100°C (212°F) (Fig. 38), water mist was not energized in this space. Investigators were sent to this compartment to check the space for fire. They confirmed the fire at 22 minutes, 46 seconds. The investigators extinguished the fire and reported that the fire was out.

Temperatures in the Engineering Storeroom remained below 50°C (122°F) for the entire demonstration. CPO Living temperatures reached approximately 80°C (176°F) within 3 minutes of the initial missile hit (Fig. 39). The water mist system was activated in modified FS mode, and temperatures in the compartment slightly decreased/increased, depending on the water mist cycle. Temperatures in the space remained below 80°C (176°F) for the remainder of the test.

9.2.6 Flooding

Flooding of the escape trunk in AMR No. 1 was first reported by investigators 10 minutes, 49 seconds after the initial missile hit. This information was entered into the SCS by DCC personnel. One minute, 14 seconds later (12 minutes, 3 seconds), the Casualty Coordinator reported flooding in AMR No. 1 and dispatched the Attack Team to contain the flooding. At 17 minutes, 10 seconds, the DCO directed a status report from the Casualty Coordinator on the flooding in AMR No. 1. The Casualty Coordinator reported that flooding was in MMR No. 1, not AMR No. 1; DCC personnel updated the SCS to reflect this information. Approximately 23 minutes, 11 seconds after the demonstration was started, the Casualty Coordinator reported that progressive flooding in MMR No. 1 was under control, and that the Attack Team was making repairs. At 30 minutes, 18 seconds, the Casualty Coordinator reported that plugging repair in MMR No. 1 was complete.

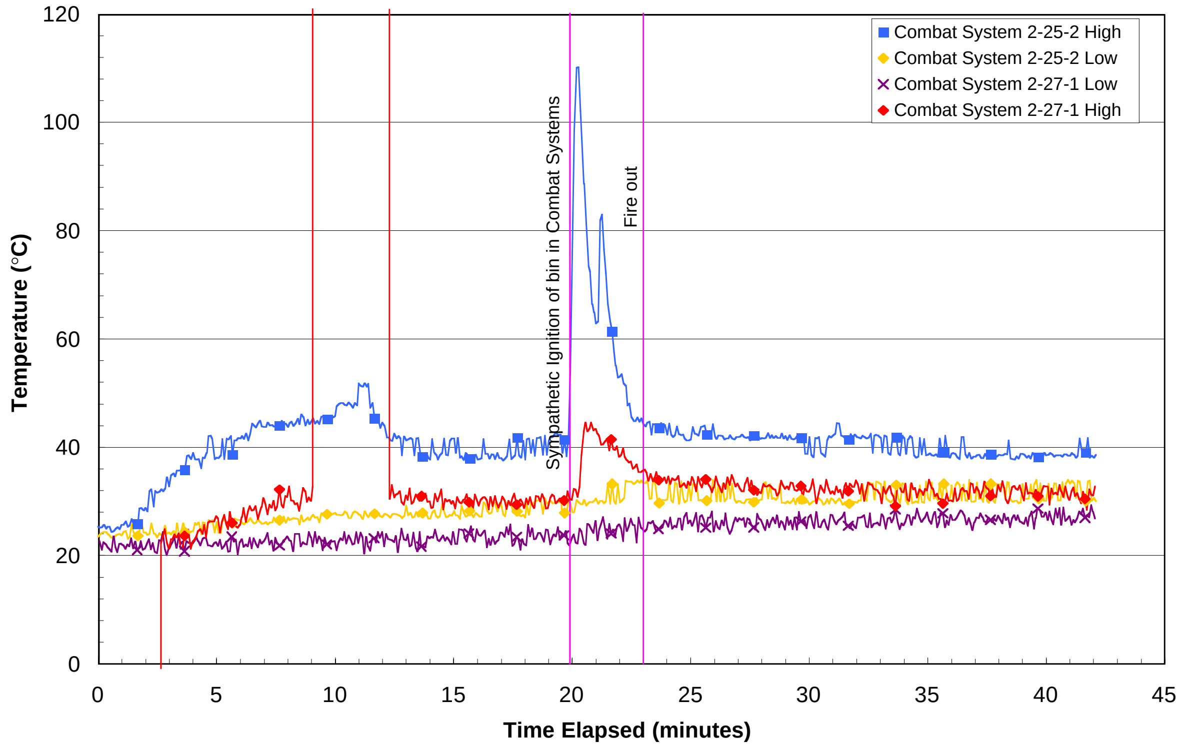


Fig. 38 — Temperatures in the Combat System Office, demonstration arm3w06

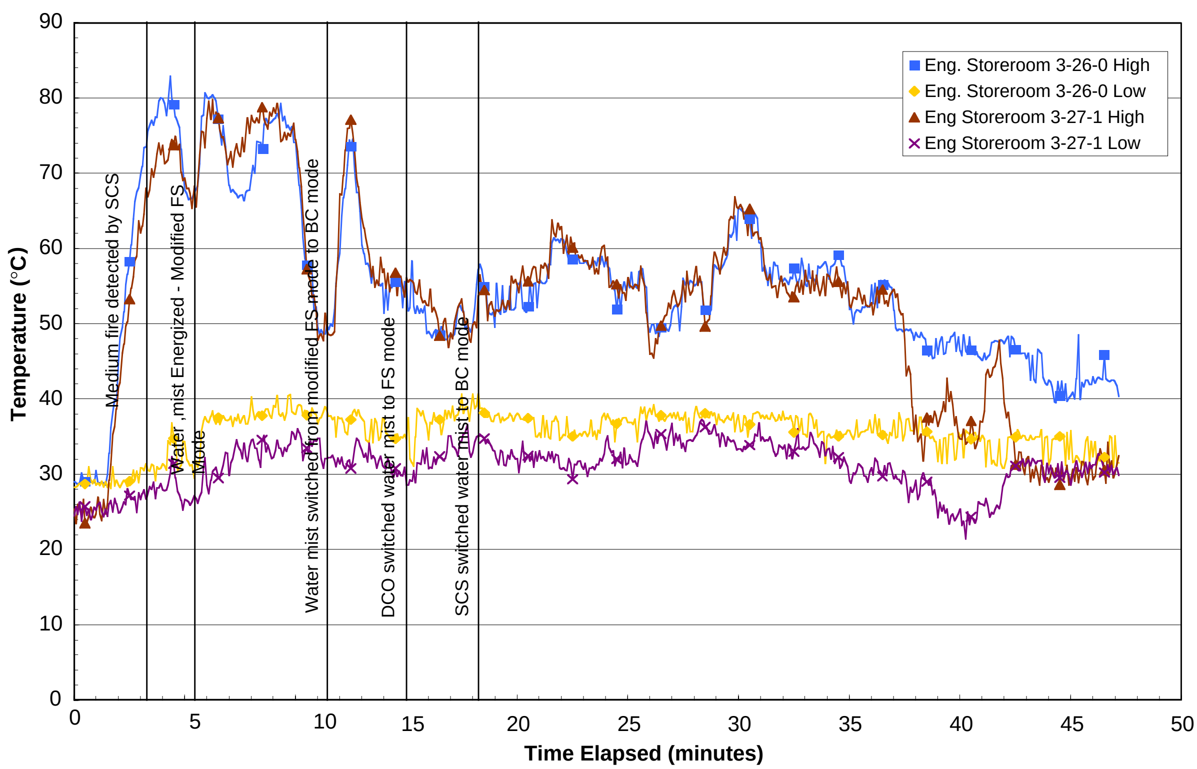


Fig. 39 — Temperatures in the Engineering Storeroom, demonstration arm3w07

9.2.7 Smoke Control Effectiveness

Smoke was reported by the investigators in Combat System Office approximately 8 minutes, 30 seconds after the demonstration was started. As requested by the Casualty Coordinator, the SES was activated approximately 3 minutes after smoke was first reported by the investigators. Smoke was not reported by the SCS because visibility in the passageways did not fall below the set levels.

9.3 Demonstration arm3w07

9.3.1 Test-specific Parameters

For demonstration arm3w07, the Tomahawk Equipment Room, Combat System Office, Engineering Storeroom, and CPO Living were selected as the locations for sympathetic ignition. The Combat System Office, Tomahawk Equipment Room, and Engineering Storeroom each contained one bin of fuel, while CPO Living contained four bunks with bedding material. Progressive flooding was also included in MMR No. 1. The fire main rupture was initiated in the 2nd deck starboard passageway. (This was the first test in which a fire main rupture and flooding were simultaneously activated.)

9.3.2 General Results

The PDA was identified by the SCS Damage Characterization function in 19 seconds. Fully involved fires were identified in the Comm Center, Radio Transmitter Room, Tomahawk Equipment Room Vestibule, CIC, and Crew Living. Within 27 seconds of the missile hit, the SCS Water Mist Control function automatically set fire boundaries by engaging the water mist system in BC mode in the APDA compartments (CPO Living, Tomahawk Equipment Room, Engineering Storeroom, Combat System Office, Operations Office, and CSMC/Repair 8). At 31 seconds, the DCO reviewed the damaged areas with the BDAT and directed an investigation of the damage area.

One minute, 11 seconds after the start of the demonstration, personnel in the Control Room initiated the fire main rupture. Within 57 seconds, the SCS Fire Main Control function automatically detected and isolated the rupture. At 1 minute, 13 seconds, the SCS Automated Decision Aid function recommended setting manual fire boundaries in the 2nd Deck passageways. Four seconds later, the DCO directed this order to Repair 2.

Temperatures in CPO Living immediately began to rise after the fires in the PDA were ignited. At 2 minutes, 18 seconds, the SCS Water Mist Control function energized the water mist system in CPO Living. At this time, the system was energized in BC mode (the system was on for 30 seconds and off for 1 minute, 30 seconds). Four seconds after water mist was energized, the SCS Compartment Damage Display function noted a medium fire in this compartment. Approximately 1 minute, 39 seconds later, the DCO ordered the investigators to check CPO Living for fire.

At 3 minutes, 18 seconds, the SCS Compartment Damage Display function noted a medium-size fire in the Engineering Storeroom. Additionally, the SCS Compartment Damage Display function noted a medium-size fire in the Tomahawk Equipment Room at 4 minutes, 13 seconds. The water mist system was energized in both of these compartments, based on the elevated temperatures in the spaces.

Investigators began making reports soon after they were dispatched by the DCO. At 3 minutes, 22 seconds, a report was made that the port side door to CIC (WTD 2-20-2) was hot and jammed. The forward

bulkhead in Combat System Office was reported to be hot, at 4 minutes, 40 seconds. Thirty-two seconds later, the investigators confirmed a small fire in Combat System Office. Subsequently, the SCS Water Mist Control function automatically switched the water mist system in Combat System Office and Engineering Storeroom to modified FS mode (the system pulsed on and off at 20-second intervals).

Five minutes, 29 seconds after the start of the demonstration, the investigators reported that the Operations Office was hot. At 5 minutes, 58 seconds, Investigation Team #2 was sent to the Tomahawk Equipment Room Vestibule to check for fire. At 7 minutes, 15 seconds, Investigation Team #1 reported that the door to AMR No. 1 was cool. The DCO ordered the investigators to attempt access into AMR No. 1. One minute, 51 seconds later, the investigators reported that there was approximately 4 feet of water in the escape trunk in AMR No. 1.

At 8 minutes, 22 seconds, the Casualty Coordinator reported that manual fire boundaries were set on the 2nd Deck. Nine minutes, 41 seconds after the simulated missile hit, the investigators reported that the deck in CSMC/Repair 8 was hot and confirmed that there was no fire in this space. At 10 minutes, 14 seconds, a report on the status of CPO Living had not been made; Investigation Team #2 was sent to this compartment to verify the extent of damage.

At 11 minutes, 44 seconds, personnel reported progressive flooding on the lower level of MMR No. 1. Forty-three seconds later, the DCO ordered the Casualty Coordinator to send an Attack Team to MMR No. 1 to contain the reported progressive flooding.

At 12 minutes, 5 seconds, the DCO ordered an indirect attack of CIC, from CSMC/Repair 8. The DCO continued to direct the BDAT to report the status of various compartments including CPO Living, the Tomahawk Equipment Room and the Tomahawk Equipment Room Vestibule. At 14 minutes, 12 seconds, Investigation Team #2 reported that CPO Living was hot and verified that there was no fire in this compartment. At 14 minutes, 32 seconds, the investigators reported that there was no fire in the Tomahawk Equipment Room. One minute, 46 seconds later the investigators incorrectly reported that the door to the Tomahawk Equipment Room Vestibule was jammed.

At 16 minutes, 29 seconds, the Casualty Coordinator reported that there was no apparent fire in CIC. He also reported that the Attack Team was in the process of performing indirect cooling. At 17 minutes 43 seconds, investigators reported that there was no fire in Combat System Office. The DCO sent an investigation team to confirm the status of the Tomahawk Equipment Room Vestibule at 18 minutes, 13 seconds. Approximately 2 minutes later, investigators reported that there was no fire in this space.

Nineteen minutes, 11 seconds after the missile hit, an Attack Team reported a fire in the Comm Center. At 21 minutes, 44 seconds, the DCO ordered the indirect attack to be secured so personnel could perform a direct attack on the fire in the Comm Center. The DCO then sent Investigation Team #1 to determine if the Comm Center was accessible, since reports of this nature had not been made. The Attack Team was ordered to standby until access to the Comm Center was made. At 23 minutes, 45 seconds, the Indirect Attack Team resumed indirect cooling while the status of the Comm Center was being determined. At 26 minutes, 59 seconds, the investigators reported the starboard door to the Comm Center was hot and jammed. The DCO ordered Repair 2 to forcibly enter the Comm Center using the exothermic torch.

At 29 minutes, 13 seconds, personnel in Repair 2 reported that progressive flooding in MMR No. 1 had been stopped and the flood watch was set. Approximately 31 minutes, 26 seconds after the start of the demonstration, access to the Comm Center was made and the Attack Team was reported to be entering the

space. Prior to the start of the direct attack, the DCO confirmed that the indirect attack had been secured. One minute, 5 seconds later, Repair 2 reported the fire in the Comm Center was out and the reflash watch was set.

Personnel were then sent to confirm the status of the fires in the Radio Transmitter Room and Crew Living. At 34 minutes, 25 seconds, Repair 2 reported a fire in the Radio Transmitter Room. Approximately 14 seconds later, Repair 2 reported that the fire had been extinguished. The DCO sent Investigation Team #1 to Crew Living at 34 minutes, 50 seconds. Approximately 8 minutes, 14 seconds later, the Casualty Coordinator reported that there was no fire in Crew Living. At this time, all fires in the PDA were reported extinguished and the demonstration was complete.

9.3.3 Identification of the Fires/Water Mist System Operation

The SCS Damage Characterization function noted fully involved fires in the Comm Center, Radio Transmitter Room, Tomahawk Equipment Room Vestibule, CIC, and Crew Living within 19 seconds of the missile hit. The SCS Water Mist Control function attempted to energize the water mist system in BC mode in CPO Living, 2 minutes 18 seconds after the start of the test. Four seconds later, the SCS Compartment Damage Display function notes a medium-size fire in CPO Living. At this time, compartment temperatures exceeded 80°C (176°F). Temperatures in the compartment continued to rise, and the SCS Water Mist Control function automatically attempted to switch the water mist system to FS mode. The investigators reported that the compartment was hot, but there was no fire. Temperatures still increased and eventually exceeded 200°C (392°F). The compartment temperatures were rising because the compartment water mist solenoid control valve was temporarily stuck in the closed position. At 16 minutes, 14 seconds, water mist was switched to BC mode. At this time, water mist was energized and temperatures in the compartment immediately decreased.

At 3 minutes, 18 seconds, a medium-size fire was noted by the SCS Compartment Damage Display function in the Engineering Storeroom. The compartment temperatures approached 80°C (170°F) when the SCS Water Mist Control function energized the water mist system in BC mode, 48 seconds later. At 5 minutes, 28 seconds, water mist was switched to modified FS mode. The water mist system was switched between BC mode and modified FS mode for the remainder of the test, based on the request of the DCO or automated actions by the SCS (Fig. 39).

Sympathetic ignition of the bin in the Tomahawk Equipment Room occurred 3 minutes, 35 seconds after the start of the demonstration. At 4 minutes, 6 seconds, the SCS Water Mist Control function activated the water mist system in the BC mode. Within 40 seconds of ignition, the SCS Compartment Damage Display noted a medium-size fire and the SCS switched the water mist system to modified FS mode. When water mist was switched to modified FS mode, compartment temperatures were in excess of 200°C (392°F). The investigators reported that there was no fire in the Tomahawk Equipment Room at 14 minutes, 30 seconds. At this time, the SCS Water Mist Control function switched the water mist system back to the BC mode (Fig. 40).

At 5 minutes, 12 seconds, the investigators reported a fire in Combat System Office. This fire was classified as a small fire by the SCS, since compartment temperatures were less than 75°C (167°F). The SCS Water Mist Control function activated the water mist system in the modified FS mode (the system pulsed on and off at 20-second intervals). At 17 minutes, 43 seconds, a report was made that there was no fire in the compartment. The fire was cleared from SCS, and the water mist system was switched back to BC mode.

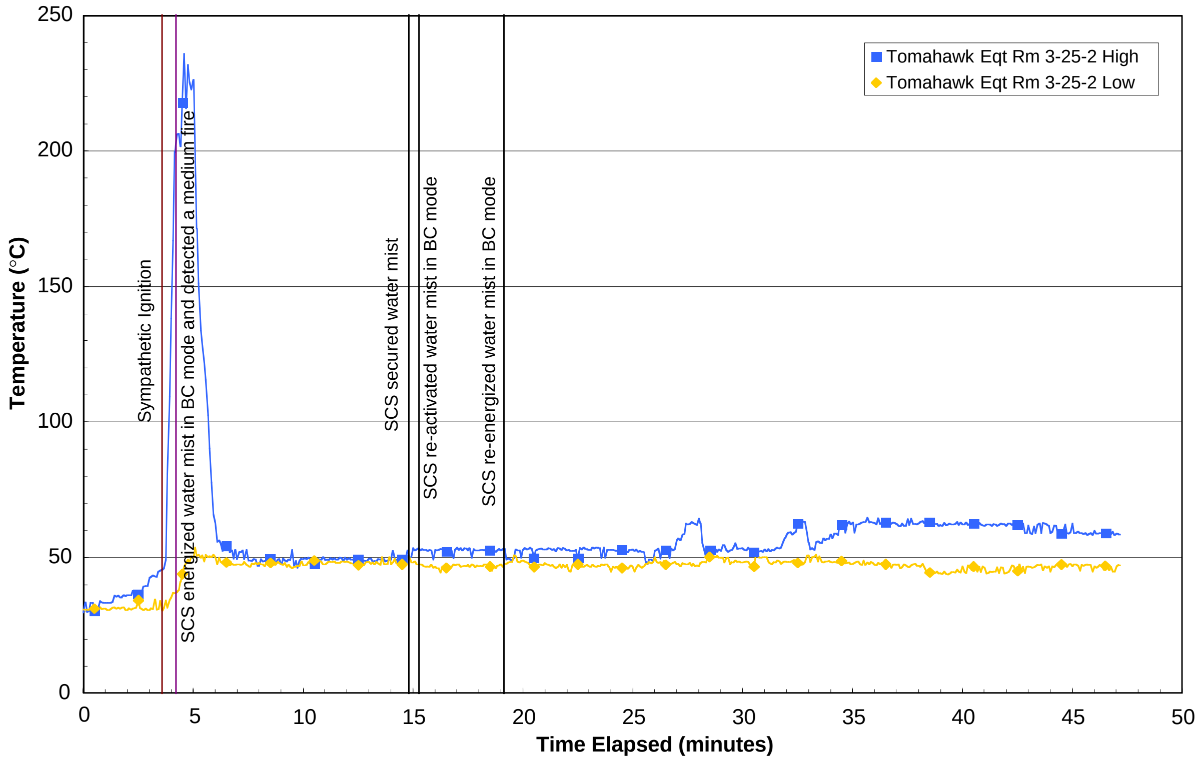


Fig. 40 — Temperatures in Tomahawk Equipment Room, demonstration arm3w07

At the start of the demonstration, the SCS Casualty Characterization function incorrectly included the Tomahawk Equipment Room Vestibule as part of the PDA. This was because of the induced sensor damage that was activated at the onset of the missile hit. Approximately 5-1/2 minutes later, the DCO sent the investigators to the Tomahawk Equipment Room Vestibule to check the space for the detected fire. At 15 minutes, 39 seconds, the investigators incorrectly reported that the door to the space was jammed, but not hot. The second investigation team was again sent to confirm this report at 18 minutes, 43 seconds. The investigators this time correctly reported that the access to the space was clear and that there was no fire in this space. Within 20 minutes, the DCO had completed all of the recovery actions for the APDA spaces.

9.3.4 Fire Main Rupture

Personnel in the Control Room initiated the fire main rupture 1 minute, 11 seconds after the start of the demonstration. Within 17 seconds, the SCS Fire Main Control function had identified a potential fire main rupture. At this time, the SCS Fire Main Control function automatically began to close the appropriate valves to isolate the rupture. Forty seconds later, the fire main rupture was isolated.

The SCS Fire Main Control function initially isolated a larger portion of the fire main than was necessary because of a misinterpretation of the simultaneous Main Space flooding casualty activation. This less-than-optimum isolation was attributed to a misadjusted pressure sensor in one of the fire main smart valves located on the starboard side 2nd Deck passageway.

9.3.5 Fire Boundaries

Within 27 seconds of the start of the demonstration, the SCS Water Mist Control function automatically set fire boundaries in the APDA compartments by activating the water mist system in BC mode. Although the system was activated in BC mode, water mist was not energized until compartment temperatures reached 60°C (122°F). Manual fire boundaries on the 2nd Deck were ordered by the DCO at 1 minute, 17 seconds based on recommendations from the SCS Automated Decision Aid function. At 8 minutes, 22 seconds, the Casualty Coordinator reported that all manual fire boundaries were set.

9.3.6 Compartment Temperature Profiles

Before the indirect attack of CIC was started, the overhead temperatures in the Comm Center exceeded 600°C (1112°F) and temperatures in CIC reached approximately 230°C (446°F). Figures 41 and 42 show temperatures in the CIC and Comm Center, respectively. The Attack Team began indirect cooling of CIC from CSMC/Repair 8 within 17 minutes of the missile hit. The overhead temperatures in CSMC/Repair 8 increased by approximately 20°C (68°F) when the indirect attack was started. However, temperatures in this compartment were tenable and remained below 60°C (140°F) while the indirect attack was conducted.

When the indirect attack began, temperatures in the Comm Center and CIC immediately decreased. Temperatures in the Comm Center dropped below 200°C (392°F), and temperatures in CIC remained less than 120°C (248°F). The direct attack of the fire in the Comm Center was started approximately 32 minutes after the missile hit. The direct attack resulted in additional cooling of the space.

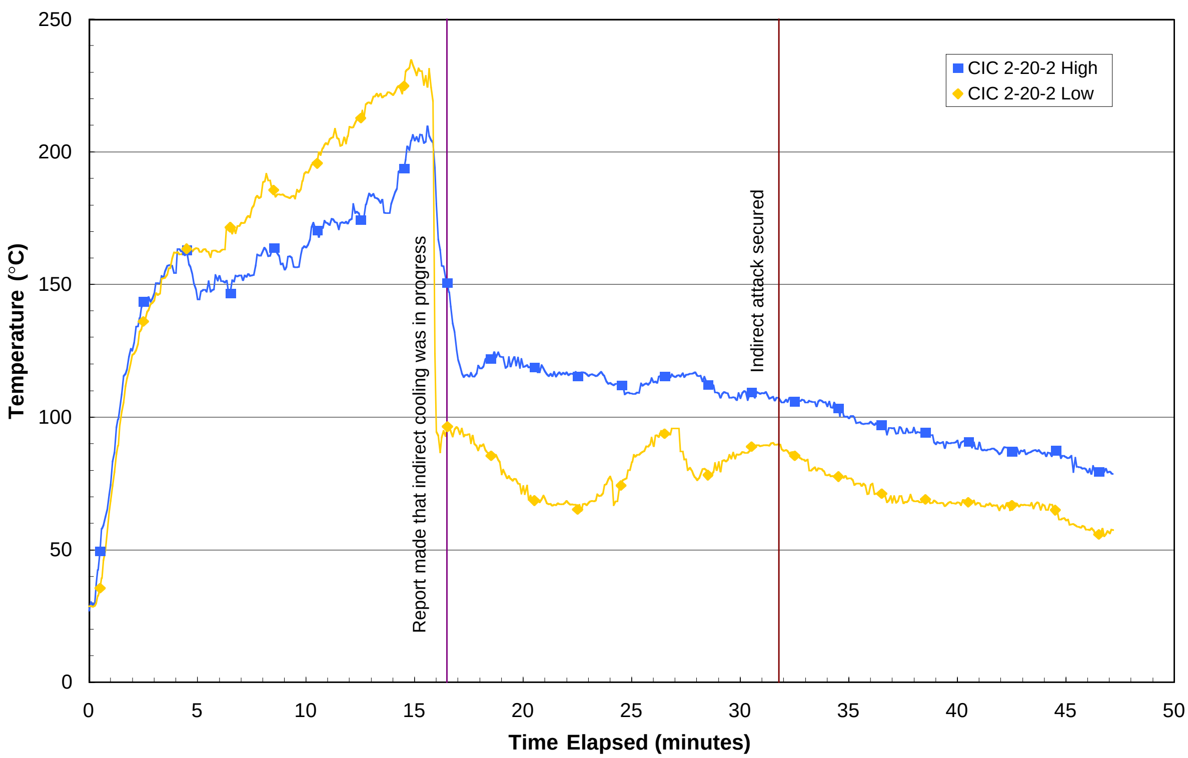


Fig. 41 — Temperatures in CIC, demonstration arm3w07

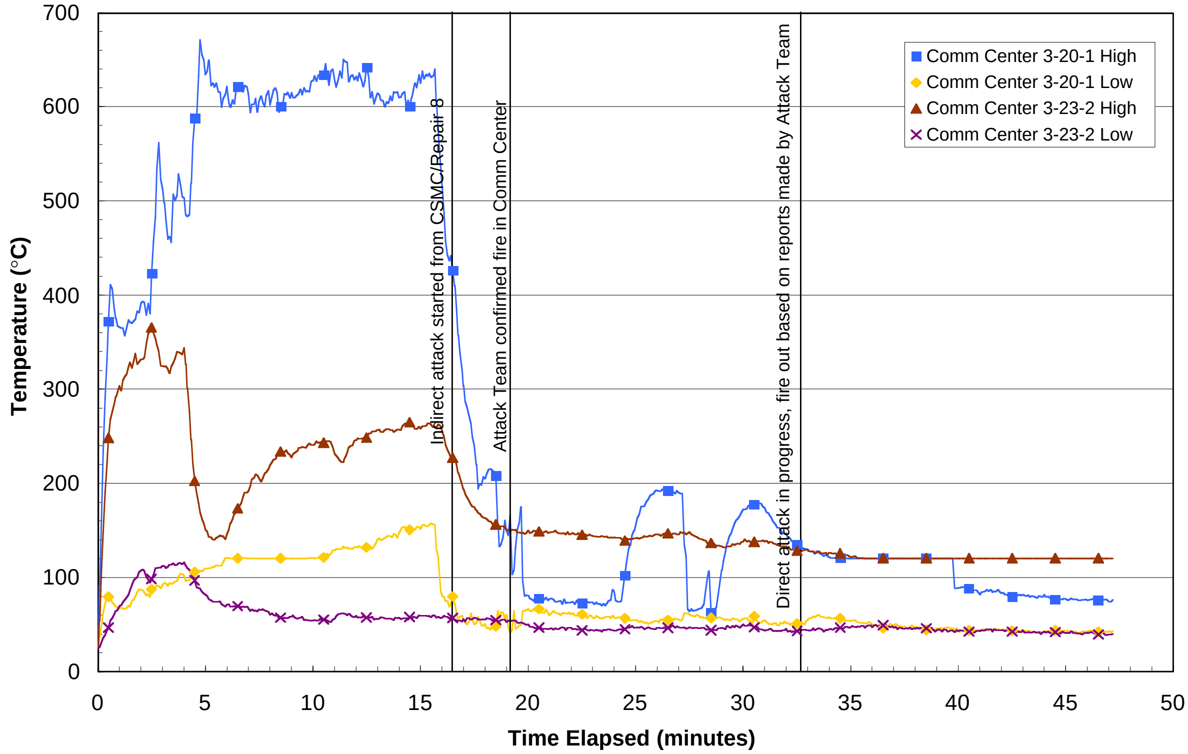


Fig. 42 — Temperatures in the Comm Center, demonstration arm3w07

Sympathetic ignition of the bin in the Tomahawk Equipment Room occurred at 3 minutes, 35 seconds. Compartment temperatures peaked at approximately 230°C (446°F). The water mist system, which was engaged in modified FS mode, quickly extinguished the fire and effectively maintained the compartment temperatures around 50°C (122°F). The BDAT reported a small fire in the Combat System Office approximately 5 minutes after the start of the test. At this time, compartment temperatures were approximately 33°C (92°F). The water mist system was activated in modified FS mode within 30 seconds. The temperatures in the compartment increased slightly when the water mist system was activated but remained below 45°C (113°F).

As discussed in Section 9.3.3, water mist in CPO Living was not actually energized until 16 minutes, 14 seconds after the start of the demonstration. This was due to a temporary mechanical problem with the compartment water mist solenoid control valve. This resulted in rising compartment temperatures (temperatures exceeded 200°C (392°F)), even though the water mist system was activated. Once the affected water mist system solenoid valve opened, compartment temperatures immediately decreased to below 100°C (212°F).

Approximately 4 minutes, 30 seconds after the start of the test, temperatures in the Engineering Storeroom briefly exceeded 80°C (176°F). Water mist was activated in modified FS mode. Temperatures in the compartment remained below 80°C (176°F) and eventually decreased to below 70°C (158°F).

9.3.7 Flooding

Seven minutes, 15 seconds after the start of the demonstration, Investigation Team #1 reported that the door to AMR No. 1 was cool. The DCO ordered the investigators to determine whether this compartment

was accessible. At 9 minutes, 6 seconds, the investigators reported that approximately 4 feet of water was in the AMR No. 1 escape trunk. DCC personnel entered this information into the SCS.

At 11 minutes, 44 seconds, Investigators reported that there was progressive flooding on the lower level of MMR No. 1. At 12 minutes, 15 seconds, an Attack Team was sent to MMR No. 1 to stop the progressive flooding. Approximately 20 minutes, 54 seconds after the initial missile hit, the Casualty Coordinator reported that the plugging repair in MMR No. 1 was 50% complete. At 28 minutes, 22 seconds, Repair 2 reported that the plugging repair was 100% complete and the floodwater in the bilge was being dewatered with the installed drainage system. From the time of detection, the flood repair took 17 minutes.

9.3.8 Smoke Control Effectiveness

At 7 minutes, 50 seconds, the Casualty Coordinator requested activation of the smoke ejection system. This was activated by the DCO within 15 seconds. At the time of activation, no smoke was detected in the passageways by the ODMs. The system maintained smoke-free conditions within the passageways throughout the remainder of the exercise.

9.4 Demonstration arm3w08

9.4.1 Test-specific Parameters

For demonstration arm3w08, the Tomahawk Equipment Room, Combat System Office, Engineering Storeroom, and CPO Living were selected as the locations for sympathetic ignition. The Combat System Office, Tomahawk Equipment Room, and Engineering Storeroom each contained one bin of fuel, while CPO Living contained four bunks with bedding material. One of these bunks was configured with an additional load of combustibles that included laundry and newspaper. Progressive flooding was included in MMR No. 1 and a fire main rupture was initiated in the Operations Office.

9.4.2 General Results

The SCS Damage Characterization function identified the PDA within 21 seconds of the simulated missile hit. The SCS Compartment Damage Display noted fully involved fires in Comm Center, Radio Transmitter Room, CIC, and Crew Living. Six seconds later, the SCS Water Mist Control function automatically began to set fire boundaries by activating the water mist system in BC mode in the APDA compartments. At 46 seconds, the DCO directed the BDAT to investigate the damage area. The SCS Compartment Damage Display also incorrectly noted a fire in CSMC/Repair 8 approximately 1 minute after the start of the test.

At 1 minute, 7 seconds, the DCO ordered Repair 2 to set manual fire boundaries on the 2nd Deck passageways. At 1 minute, 23 seconds, personnel in the Control Room initiated the fire main rupture in the Operations Office. The SCS Fire Main Control function detected and isolated this rupture within 1 minute, 30 seconds.

Two minutes, 44 seconds after the missile hit, the DCO used the SCS Surveillance Video function to note that there was no fire in CSMC/Repair 8. At 3 minutes, 39 seconds, Repair 2 reported manual fire boundaries were set on the 2nd Deck. The investigators reported that the starboard door to CIC was jammed and warm at 4 minutes, 6 seconds. Approximately 21 seconds later, the port door to CIC was reported to be hot and jammed.

Sympathetic ignition of the bin in the Engineering Storeroom occurred at 5 minutes, 23 seconds. The DCO noted the fire ignition using the SCS Surveillance Video system. Forty-five seconds later, Investigation Team #2 was sent to investigate the fire. Based on the elevated temperatures in the Engineering Storeroom, a medium fire was detected by the SCS Compartment Damage Display at 6 minutes, 13 seconds.

At 6 minutes, 3 seconds, the Safety Team ignited the staged combustible material. The investigators continued to make reports on the status of fire in the compartments. The BDAT reported that the Combat System Office and the Operations Office were clear at 6 minutes, 33 seconds and 6 minutes, 42 seconds, respectively. The SCS Compartment Damage Display noted a fire in the Tomahawk Equipment Room at 7 minutes, 5 seconds. Investigation Team #2 was dispatched to investigate the Tomahawk Equipment Room fire.

At 7 minutes, 58 seconds, the SCS Compartment Damage Display noted a medium-sized fire in CPO Living. Based on the fire compartment location, a manual fire boundary was ordered by the DCO in the forward Repair 2 passageway at 8 minutes, 27 seconds. At 8 minutes, 38 seconds, the bin in the Combat System Office sympathetically ignited. The DCO observed this fire ignition with the SCS Surveillance Video. At 9 minutes, 9 seconds, Investigation Team #2 was sent to Combat System Office.

Ten minutes, 12 seconds after the simulated missile hit, the BDAT reported that there was no fire in the Tomahawk Equipment Room. Approximately 11 minutes after the start of the test, the investigators reported the fire in Combat System Office was out.

At 11 minutes, 19 seconds, the DCO directed Investigation Team #2 to report the status of the fire in CPO Living. At 12 minutes, 58 seconds, personnel in the Engineering Storeroom requested that water mist be secured to facilitate their investigation. The fire in this space was reported out at 14 minutes, 44 seconds.

Fourteen minutes, 35 seconds after the simulated missile hit, the Attack Team was directed to conduct indirect cooling of CIC from CSMC/Repair 8. At 15 minutes, 18 seconds, Investigation Team #2 reported a fire in CPO Living. The investigators reported that MMR No. 1 was clear at 16 minutes, 12 seconds. The DCO directed the investigators to determine whether the Comm Center was accessible. At 18 minutes, 23 seconds, the indirect attack of CIC was started.

At 21 minutes, 42 seconds, the SCS Compartment Damage Display noted a fully involved fire in the Combat System Office. At the same time, the investigators reported that the access to the Comm Center was hot and jammed. Twenty-three minutes, 25 seconds after the start of the test, the DCO directed a forcible entry into that the Comm Center. The DCO then directed Investigation Team #2 to verify the status of the Combat Systems Office. At 25 minutes, 36 seconds, the investigators reported that there was no fire in the Combat System Office. At 25 minutes, 55 seconds, investigators were sent to CPO Living to check elevated temperatures in the compartment. A report was made approximately 1 minute, 12 seconds later that there was no fire in this compartment. The fire had self-extinguished before the water mist system was energized.

Twenty-eight minutes, 10 seconds after the start of the demonstration, Repair 2 reported that the Support Team had gained access to the Comm Center. At this time, the indirect attack was secured and the DCO ordered a direct attack on the Comm Center. At 30 minutes, 25 seconds, Investigation Team #1 confirmed that there was a fire in the Comm Center. The direct attack of the fire in this space was started approximately 1 minute, 48 seconds later. The fire was reported out at 33 minutes, 34 seconds.

A Class A fire in the Radio Transmitter Room was reported at 34 minutes. This fire was reported out approximately 1 minute later. The Attack Team was sent to Crew Living to check for possible fire in this

space. At 38 minutes, 36 seconds, Investigation Team #2 reported that there was no fire in CIC. At 41 minutes, 31 seconds, the Repair 2 reported that the re-flash watch was set in the Comm Center and Radio Transmitter Room and that the Attack Team was still investigating Crew Living. Approximately 47 minutes, 32 seconds after the start of the demonstration, Repair 2 reported that there was no fire in Crew Living. At this time, the DCO reported all fires were out and the test was complete.

9.4.3 Identification of the Fires/Water Mist System Operation

Within 21 seconds of the start of the demonstration, the SCS Damage Characterization function noted fully involved fires in the Comm Center, Radio Transmitter Room, CIC, and Crew Living. Approximately 1 minute after the start of the test, a transient electronic thermocouple signal induced a temperature spike in CSMC/Repair 8 that resulted in an incorrect fire alarm by the SCS Compartment Damage Display. The SCS Water Mist Control function automatically switched the water mist system to FS mode. The DCO used the SCS Surveillance video to correctly confirm that no fire was in this compartment, and switched the water mist system back to BC mode for boundary maintenance. While activated in BC mode, the water mist system was energized for approximately 30% of the time (on for 60 seconds, off for 2 minutes, 20 seconds). Throughout the test, temperatures in CSMC/Repair 8 did not exceed 50°C (122°F).

Sympathetic ignition of the bin in the Engineering Storeroom occurred at 5 minutes, 23 seconds. The fire was first observed by the DCO using the SCS Surveillance video. The SCS Compartment Damage Display noted a medium-size fire at 6 minutes, 13 seconds, and the SCS Water Mist Control function activated the water mist system in the FS mode at 6 minutes, 58 seconds. At the time water mist was activated, temperatures in the compartment exceeded 150°C (302°F). Compartment temperatures quickly reduced when the water mist system was activated. Within 3 minutes, compartment temperatures were approximately 50°C (140°F), and the SCS Water Mist Control function automatically switched the water mist system to modified FS mode (the system pulsed on and off at 30-second intervals). Water mist was secured by DCC at 13 minutes, 6 seconds to enhance investigation operations in the space. The system was reactivated by the DCO approximately 1-1/2 minutes later. Figure 43 displays the compartment temperatures in the Engineering Storeroom.

Safety Team personnel ignited the bedding materials in CPO Living approximately 6 minutes after the test began. The investigators first reported this fire approximately 2 minutes after it was ignited. Subsequently, the SCS Compartment Damage Display noted a medium-size fire in this compartment. Prior to this demonstration, the water mist branchline serving CPO Living was intentionally deactivated to further represent system damage. DCC personnel were not aware of the water mist system unavailability since the current ex-Shadwell water mist system does not have a feedback signal from the solenoid control valve. When the SCS Water Mist Control function attempted to activate water mist in CPO Living, no water was actually discharged. The presence of smoke obscured the visibility in the compartment and limited the effectiveness of the SCS Surveillance video to validate water mist operation.

At 9 minutes, the water mist system in CPO Living was automatically switched to FS mode by the SCS Water Mist Control function as the result of rising temperatures in the compartment. Approximately 2 minutes later, the temperatures in CPO Living exceeded 232°C (450°F), and the SCS Casualty Characterization function reclassified the fire as a large fire (Fig. 44). DCC personnel were still not aware that the water mist system was not functioning in CPO Living because of poor visibility in the compartment and the lack of a feedback signal to note there was no water flow. At 15 minutes, 18 seconds, the investigators and the DCO secured the water mist system.

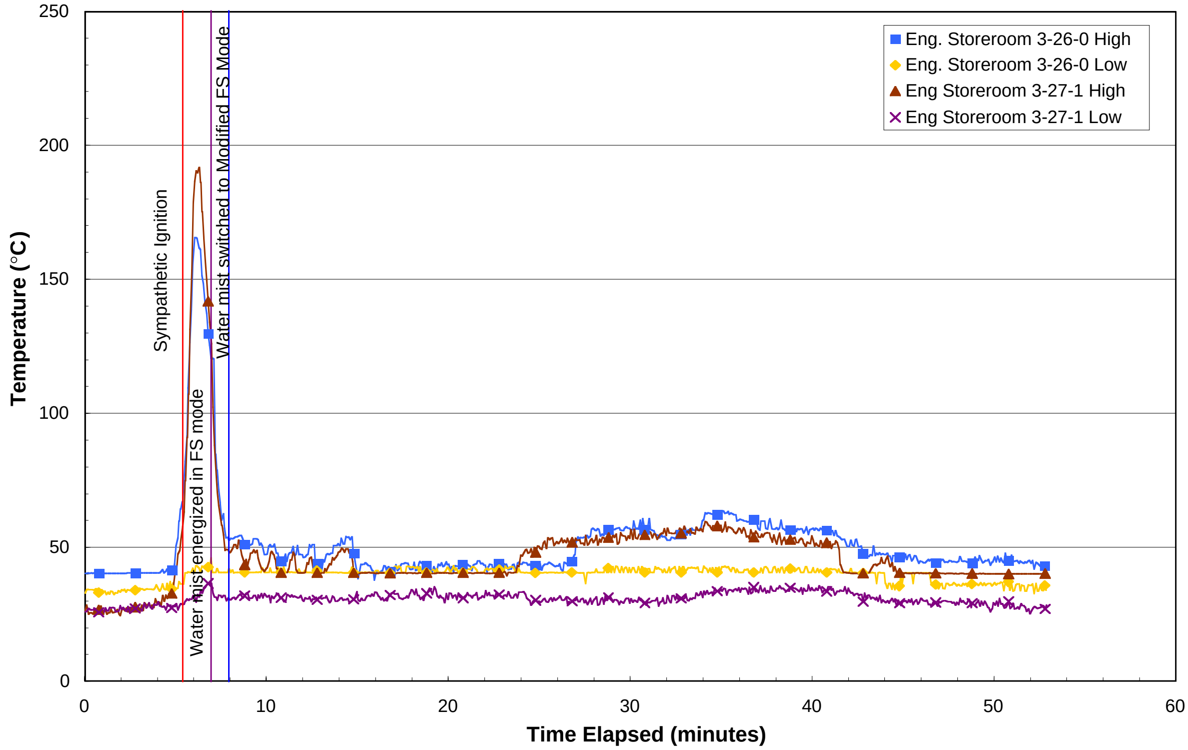


Fig. 43 — Temperatures in Engineering Storeroom, demonstration arm3w08

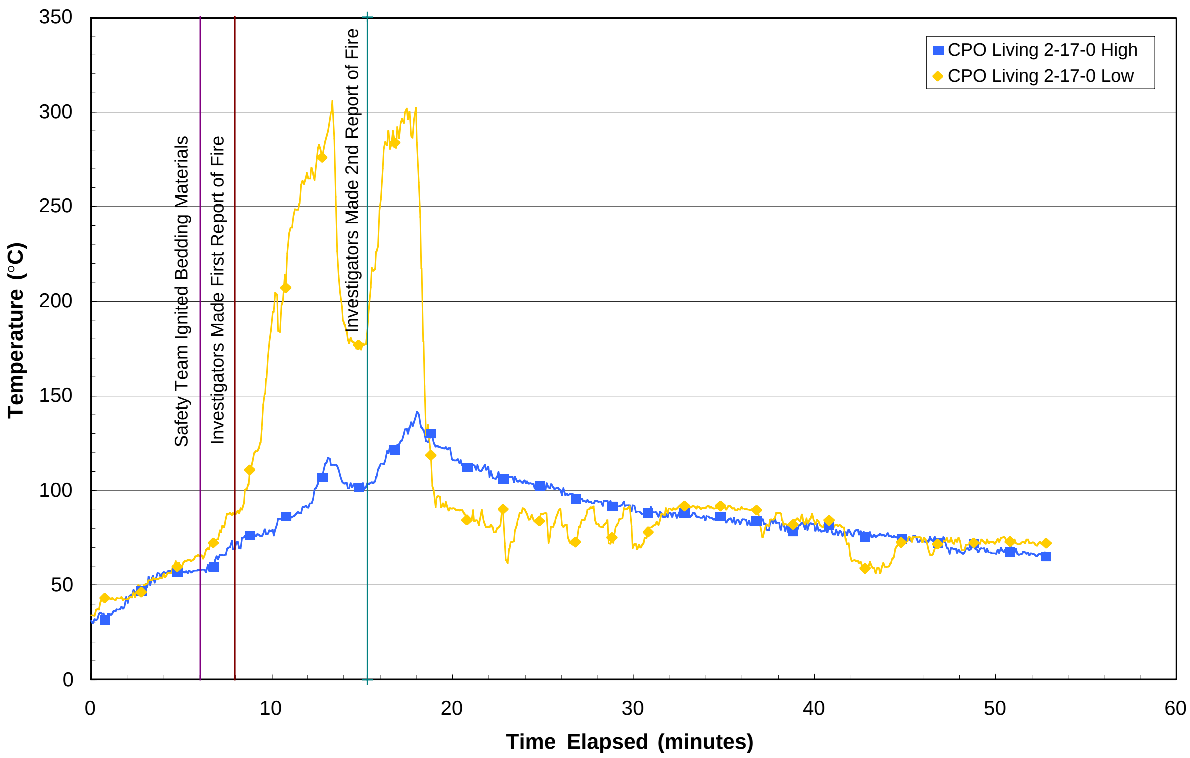


Fig. 44 — Temperatures in CPO Living, demonstration arm3w08

At 7 minutes, 5 seconds, a medium-size fire was in the Tomahawk Equipment Room by the SCS Compartment Damage Display. At this time, the compartment temperatures were approximately 80°C (176°F). Approximately 30 seconds later, the SCS Water Mist Control function energized the water mist system in the BC mode. When the system was activated in BC mode, water mist was energized for approximately 25% of the BC cycle (on for 60 seconds, off for 2 minutes, 40 seconds).

At 8 minutes, 38 seconds, sympathetic ignition of the bin in Combat System Office occurred. The fire was observed by the DCO using the SCS Surveillance Video at approximately 9 minutes after the start of the test. This fire was extinguished by the water mist system before the investigators arrived on-scene.

9.4.4 Fire Main Rupture

The fire main rupture in the Operations Office was initiated approximately 1 minute, 23 seconds after the start of the demonstration. Within 1 minute, 30 seconds, the SCS Fire Main Control function automatically identified and isolated the fire main rupture.

9.4.5 Fire Boundaries

The SCS Water Mist Control function automatically activated the water mist system in BC mode for the APDA compartments within 27 seconds of the missile hit. By engaging the water mist system in BC mode, fire boundaries were set in the compartments where water mist was available. At 1 minute, 7 seconds, the DCO ordered manual boundaries in the passageways on the 2nd deck based on recommendations from the SCS Automated Decision Aid function. Repair 2 reported that fire boundaries were set approximately 2 minutes, 30 seconds later.

At 8 minutes, 4 seconds, a medium fire was detected in CPO Living by the investigators. As a result of this fire, CPO Living was no longer considered a boundary compartment, and boundaries were needed outside of this space (Fig. 44). At 8 minutes, 27 seconds, the DCO ordered a manual fire boundary to be set in the passage outside of Repair 2. A report was not made on the status of this boundary. However, based on the proximity to the Repair 2 Locker, it is reasonable to assume that this boundary was set and maintained within seconds of being ordered. This additional manual fire boundary was set because the DCO correctly surmised that the water mist system in CPO Living was not functioning properly.

9.4.6 Compartment Temperature Profiles

The overhead temperatures in the Comm Center exceeded 600°C (1112°F) before indirect cooling was started (Fig. 45). Eighteen minutes, 23 seconds after the simulated missile hit, an Attack Team started indirect cooling of CIC from CSMC/Repair 8. When the indirect attack was started, temperatures in CSMC/Repair 8 increased slightly as the result of the scuttle being opened.

Temperatures in the compartment remained low, below 50°C (122°F), while personnel conducted indirect cooling of CIC. Immediately after indirect cooling was started, temperatures in the Comm Center and CIC decreased. The direct attack of the fire in the Comm Center was started 32 minutes, 13 seconds after the missile hit. The direct attack provided additional cooling of the compartment.

Temperatures in the Engineering Storeroom reached approximately 190°C (375°F) as the result of sympathetic ignition of the bin in this space. The water mist system worked effectively to extinguish this fire and cool the compartment to approximately 50°C (122°F). The water mist system was not functioning in CPO Living during this demonstration, and the compartment temperatures in this space reached close to 300°C

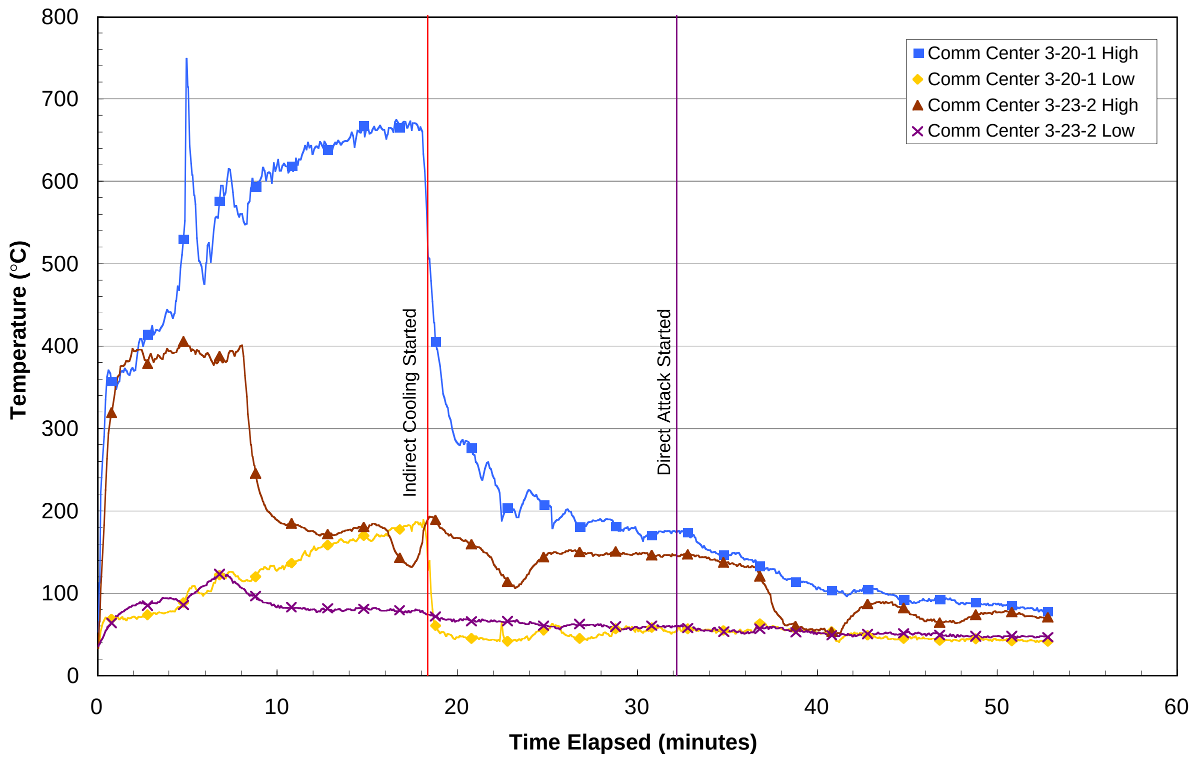


Fig. 45 — Temperatures in Comm Center, demonstration arm3w08

(572°F). The ignition of the bedding materials by Safety Team personnel contributed to the elevated temperatures in this compartment.

Sympathetic ignition of the bin in the Tomahawk Equipment Room did not occur during this demonstration. Compartment temperatures exceeded 80°C (176°F). However, the water mist system that operated in BC mode worked well to keep the bin from igniting.

10. DISCUSSION

10.1 Overall DC-ARM System Performance

The DC-ARM test series provided the Navy with the first real-scale experimental study to determine the technology requirements and DC doctrine that should be followed to enable major DC manning reductions on future naval surface combatants. The key enabling technologies that were found to contribute most to reduced manning and improved DC performance included:

- Water mist for fire suppression and fire containment,
- Sensors for fire detection and fire characterization,
- Fire main distribution controls for robust, survivable isolation of fire main ruptures,
- Smoke ejection system for clearing smoke on the DC Deck,
- Video installed in most spaces for compartment monitoring and to reduce investigation workload,
- Supervisory control system to enable effective situation awareness and overall control of the DC response, and
- New doctrine developed to integrate with the new technology.

The SCS, combined with the other DC-ARM technology, enabled effective management of the DC response during the FY01 demonstration. The performance for the wartime demonstrations is summarized in Table 9 and described briefly below for Casualty Characterization, Fire Containment, Fire Control, Fire Main Rupture Isolation, and DC Management.

Table 9 — Summary of DC-ARM Key Performance Demonstrated
(Shading denotes meeting DC-ARM Objective)

DC-ARM Objectives[1]		Baseline Demo-FY 98 *No SCS Used*	FY 00 Demo *SCS w/only Remote Manual Control*	FY01 Demo *SCS w/Automation*
Identify PDA	≤ 9 min	18 min	3.3 s	3.75 s
Extinguish fires in PDA	≤ 33 min	62.5 s	N/A	37 min, 10 s
Set vertical boundaries:	≤ 9 min			
Manually		19 min, 23 s	N/A[3]	N/A[3]
Using water mist		N/A[2]	2 min, 35 s	0 min, 25 s
Set horizontal boundaries:	≤ 13 min			
Manually		13 min[4]	6 min, 15 s	4 min, 48 s
Using water mist		N/A[2]	1 min, 48 s	0 min, 25s
Isolate fire main rupture	≤ 9 min	13 min, 15 s[5]	1 min, 48 s	1 min, 22 s[6]

Notes:
1. DC-ARM objectives are based on flame spread guidelines derived from experimental data [37-42].
2. Water mist system not installed for the FY98 Baseline Demonstration.
3. No manual vertical fire bounaries were required. All vertical fire boundaries were set/maintained using the water mist system.
4. Horizontal fire boundaries could not be maintained in all tests.
5. Using only manual isolation.
6. Rupture isolation actually occurred in approximately 1 min. The rupture and associated isolation information were displayed at the DCO at 1 min, 22 s.

10.1.1 Casualty Characterization

The information provided by the SCS significantly reduced the time required to identify the PDA. Historically, defining the PDA has involved dispatching investigators and waiting for their reports of damage; this typically has taken 15 minutes or more. During the FY98 baseline demonstration, without the SCS, it took an average of 18 minutes to define the PDA. Until the PDA has been defined, the DC team cannot plan and execute an effective course of action. With the information and decision aids provided by the SCS, an initial assessment of the PDA was available almost instantaneously (4 seconds after weapon impact). With this more rapid casualty characterization, DC actions can be executed much sooner. For example, water mist was actuated to contain the fire within 25 seconds after weapon impact.

The DC-ARM SCS defines the PDA as all contiguous compartments that the SCS believes were affected by the same casualty-initiating event. To determine which compartments are included in the PDA, the

SCS looks at all available environmental sensors and categorizes the data and sensor as normal and functioning, abnormal and functioning, or nonfunctioning. Generally, contiguous compartments with abnormal data or nonfunctioning sensors are categorized as belonging to the PDA.

10.1.2 Fire Containment

In the FY01 Demonstration within 25 seconds after weapon impact, the SCS actuated the water mist system in the compartments surrounding the PDA to contain the fire. The SCS monitored the ambient conditions in each boundary compartment and automatically actuated water mist when the boundary temperature threshold was exceeded in a compartment. After the initial actuation, water mist was actuated intermittently in the compartment to minimize the amount of water used. This actuation approach was used to improve visibility and minimize potential water damage. The SCS also provided recommendations to the DCO to dispatch boundarymen to locations that required fire boundaries where water mist was not available. With the rapid information provided by the SCS, the DCO could establish manual fire boundaries (person on-scene with hose, ready to cool bulkheads) in less than 5 minutes. During the Baseline Demonstration without the SCS, it took more than 19 minutes to set vertical boundaries [1]. Previous studies have demonstrated that vertical fire spread can occur in as little as 10 minutes [37-42].

With only water mist to contain the fire, some small fires ignited in boundary spaces where combustible material was in direct contact with a bulkhead bounding the PDA. The water mist controlled such small fires until investigators arrived, completely extinguished the fire, and removed the combustible material from the bulkhead.

10.1.3 Fire Control

Using information and decision aids in the SCS, the DCO directed a methodical response to damage that used manpower efficiently and proved to be very effective at controlling damage spread. In less than 30 minutes, the DC teams accessed the PDA and controlled fires. Fires in the PDA were extinguished within 40 minutes. This performance substantially exceeds the performance demonstrated in any non-DC-ARM test aboard the ex-USS *Shadwell* in more than a decade of DC testing with Fleet personnel (see Section 10.9). Table 9 summarizes the performance demonstrated.

The substantial improvement in performance for controlling fire is attributed to the fire containment systems, automatic fire main rupture isolation, automated surveillance video, and the decision aids provided by the SCS. Since the fire containment was mostly automatic and the fire main rupture isolation was fully automatic, the DCO was able to devote more attention to fire control. The enhanced situation awareness enabled a clear understanding of where the fire was so that the fire attack could be planned and initiated quickly and conducted effectively. Finally, the SCS decision aids provided guidance that contributed to the efficient, effective use of limited manpower.

In the wartime scenarios exercised during the FY01 demonstration, the SCS decision aids recommended first an indirect fire attack from the compartment above the PDA. The indirect attack was recommended to cool the fire spaces, thereby minimizing the threat of fire spread and improving the environment for a direct attack. The SCS decision aids then recommended an access to the PDA. If information in the SCS indicated that all accesses to the PDA were damaged or inaccessible, the decision aids recommended that the DC team conduct a forcible entry into the PDA. An attack team then entered the PDA via the cut access for a direct attack on the fires. Although the FY01 performance of fire extinguishment in 37 minutes did not meet the DC-ARM overall objective of 33 minutes, the performance was close to the objective and better than the

FY98 baseline and FY00 performance of 62 minutes and 40 minutes, respectively. Past experience with Fleet doctrine evaluation tests aboard ex-USS *Shadwell* demonstrates that more realistic training by the Navy would reduce the response time even further.

10.1.4 Fire Main Rupture Isolation

Fire main rupture isolation is critical because setting manual fire boundaries and initiating manual fire attack cannot occur if the fire main is not operational. The SCS monitors the fire main conditions using information supplied by sensors in Smart Valves (also developed by NRL) installed on the fire main. Both the Smart Valves and the SCS are independently capable of rupture detection and isolation. For the FY01 SCS demonstration, the SCS was used as the primary rupture detection and isolation mechanism, with the Smart Valve device level logic (rupture path logic) operating as a backup to the SCS. Reference 15 provides additional information on DC-ARM Smart Valve. In the FY01 demonstration, the SCS isolated the rupture and restored fire main pressure to the undamaged areas in just over a minute. This is a significant improvement from the FY98 baseline demonstration where it took more than 13 minutes to manually locate and isolate the same fire main ruptures, using fire main control similar to that in DDG 51 Class ships.

10.1.5 DC Management

Also important is the subjective evaluation of the DCO's management and control of the situation. During the FY01 demonstration, DCC operated in a very professional manner. It was clear that the DCO had good situation awareness, was confident in the ability of his people and systems, and was in control of the situation. This is an improvement over the situation during the FY00 demonstration (with less situation awareness and no automation) and a significant improvement over the FY98 baseline demonstration when there was more confusion and much less situation awareness. Appendix N provides DCC test participant comments regarding the SCS.

10.2 Total-Ship Fire Protection

An optimally manned ship will require a "total-ship" fire protection strategy to enable effective minimally manned fire-fighting response operations. A water-based, distributed, high-pressure water mist system was chosen for the DC-ARM total-ship fire protection strategy because it offered a methodology to provide both effective fire suppression and area cooling using a single "universal" agent. The use of water mist also provides an opportunity to explore future anticipatory DC response capabilities that could use preemptive water sprays to help limit blast damage resulting from a shipboard weapon explosion [47].

A high-pressure water mist system was selected to reduce the water flow requirements, thus limiting potential post-fire water damage and to improve survivability performance by reducing the system pipe diameter requirements. This helps reduce the surface area exposure to weapons effect damage. Table 10 compares commercial sprinkler and water mist system parameters that are typically used for Class A fire hazard protection.

As can be seen, the use of high-pressure water mist sprays enabled the use of 40% fewer nozzles when compared to low-pressure water mist systems and a 10% reduction of the water flow requirement compared to commercial sprinkler designs.

Because of the survivable design characteristics of the high-pressure water mist system, there is also a potential to apply water inside the PDA following a weapon hit. Testing is ongoing to evaluate this feature by using sidewall nozzles designs (not currently available for low-pressure water mist) (see Section 10.6).

Table 10 — Comparison of Sprinkler and Water Mist Systems
(Public Space/Light Hazard Protection)

System Parameters	Automatic Sprinker	Low-pressure Water Mist	High-pressure Water Mist
Nozzle spacing	3-4 m	2-3 m	4-5 m
Minimum operating pressure	0.5-1 bar	12 bar	70 bar
Water application rate	5 Lpm/m^2	4.1 Lpm/m^2	0.8-0.9 Lpm/m^2

The fire protection requirement for the everincreasing numbers of electronic-type spaces presents new challenges for future ships. These spaces on present-day combatants are not protected with fixed fire protection systems and therefore rely on manual intervention for fire-fighting and fire containment operations. For a DDG 51 Class ship, this manual response contingency is apportioned to the 53-man Combat System Casualty Control Team/ Repair 8, which is also augmented by the ship's DC organization when needed. This continued reliance on human intervention for the fire protection of electronic-type spaces would be difficult to maintain on an optimally manned ship. Other issues that should to be considered for electronic space fire protection include increased weight, space, and cost requirements associated with the addition of new fixed systems; the concentration requirements associated with vaporizing liquid/ gaseous alternatives; or the impact that water-based systems may pose on electronic equipment. Additionally, there may be some special hazards that also need to be considered such as the hydrogen fluoride (HF) acid gas hazards associated with some of the gaseous alternatives (e.g., HFC 227-ea (CF_3-CHFC-CF_3; FM-200™)) [47]. The use of a Hybrid Water Mist system for electronic space fire protection is currently being investigated in the ONR Fleet Force Protection, Future Naval Capabilities (FNC), Advanced Damage Countermeasures (ADC) program.

10.3 Fire Detection/Compartment Monitoring

The DC-ARM program used a multi-criteria sensor array for early warning fire detection [24-33] and Type K, Inconel-sheathed thermocouples, (3.2-mm (0.13-in.) outside diameter and 1.6-mm (0.06-in.) inside diameter) for compartment temperature monitoring and control inputs for the SCS Water Mist Control functions. The multi-criteria sensor array provided excellent early warning fire detection with low nuisance alarm rate in comparison to the COTS smoke detectors. The current multi-criteria sensor array lacks peer-to-peer network connectivity, which limits its effectiveness to distinguishing between fire events and fire effluent products that could migrate to adjacent compartments. This present limitation affects the multi-criteria sensor array's ability to monitor and track fire-fighting and smoke control operations. The Type K thermocouples were effective in providing continuous compartment temperature monitoring and proved essential for water mist control operations. Although thermocouples are inherently fire hardened and require no external power source, they are susceptible to occasional electromagnetic interference (EMI). This was apparent when the SCS Compartment Damage Display function incorrectly noted three false-positive fire alarms during the wartime demonstrations (see Section 9). Proper and effective shielding, grounding, and control signal filtering techniques would be required to apply thermocouple technology on future ships for continuous fire and compartment monitoring. The commercialization of the DC-ARM's multi-criteria sensor array is currently being investigated within the ONR Fleet Force Protection, FNC, Real-Time Damage Detection, Assessment, and Response program.

Appendix F provides details on the techniques used to represent sensor damage during the wartime demonstration events. The true impact of weapon damage on active sensor and control system networks is not currently known. Although the loss of sensor information in the PDA would seem reasonable, the random and intermittent techniques (i.e., plus/ minus 50 times actual) used in this test series for the adjacent compartments were derived from best-guess judgments and have not been studied or validated. Real-scale weapon effects tests and modeling techniques are needed to test and evaluate the actual effects battle damage may have on remote sensor and control system networks.

10.4 Automated Smoke Control

The consequences resulting from modern weapons effects can severely limit a ship's offensive capability. Smoke (reduced visibility) is recognized as the predominant variable that will impede a timely response to maintain and restore vital ship's mission capability. The complications posed by smoke disrupts all facets of the DC problem and can cause even a relatively minor shipboard fire to cascade into a major conflagration if effective smoke control measures are not implemented early during the casualty response [49]. Smoke not only poses risk to personnel but also can promote damage spread, especially to electronic equipment [45, 50, 51]. The DC-ARM SES proved to be an effective means to automate smoke control and support minimally manned DC response operations. The SCS Decision Aid function for smoke control uses the distributed ODMs to monitor and track the effectiveness of the SES. The ODMs used are laboratory-type instruments that use an 880-nm IRLED and receptor arrangement over a 1.0-m (3.1-ft) path length [23]. A more practical sensor technology is required to provide improved shipboard smoke control monitoring capability.

10.5 Automated Surveillance Video

The SCS Surveillance Video system provided the DCO and the DC Watch Supervisor (during Condition III) with an effective tool to capture real-time situation awareness and efficiently manage their manual response (human) assets. During the peacetime demonstrations, the SCS Surveillance Video system provided a "pop-up" video of the affected compartment when the EWFD sensor determined that there was a 60% probability of a fire event. This early video image of the compartment provided the DC Watch Supervisory with an opportunity to observe first-hand the conditions within the affected compartment prior to dispatching the RRT. In some instances, this early pop-up video image was able to nullify a false-positive sensor response from the EWFD system. During the wartime demonstrations, the SCS Surveillance Video system proved very effective in observing sympathetic ignition of combustible materials in the APDA prior to a fire alarm condition, thus enabling the DCO to better direct BDAT (investigator response) operations. Although the streaming video around the APDA proved useful, it required constant vigilance on the part of the DCO to identify a pending fire condition. Developing and incorporating Machine Vision technology to eliminate the need for a continuous human interface could achieve further improvement. Machine Vision technology development is currently being investigated within the ONR Fleet Force Protection, FNC, ADC program.

10.6 Primary Damage Area Fire Fighting

It became evident during the DC-ARM FY00 demonstrations that the success of the recovery efforts in the APDA was dependent, to a certain degree, on mitigating the thermal threat presented by the uncontrolled fires within the PDA. It was initially presumed that the fixed fire-fighting systems in the PDA would be out of commission because of battle damage and manual indirect fire-fighting actions would be required. Indirect manual fire attacks were used in the FY00 and FY01 DC-ARM demonstrations using a 3.8-cm (1.5-in.) handline equipped with a vari-nozzle. Nozzle techniques were developed to take advantage of the fog stream

venturi effects to limit steam insult to the firefighter. Other potential approaches for indirect fire fighting could include the use of pyrogenic aerosol (grenade-type) canisters thrown into the compartment or the use of through-the-bulkhead water mist nozzles. Reference 52 analyzes potential advantages for discharging water mist in the PDA immediately following a weapon hit. The use of water mist “sidewall” nozzle technology for direct cooling of the PDA is currently being investigated within the ONR Fleet Force Protection, FNC, Real-Time Damage Detection, Assessment, and Response program.

10.7 DC Communications

Communications between all DC personnel were established as described in Section 4.14. As experienced during previous test series on the ex-*Shadwell*, communications using the WIFCOM system were problematic. Investigation Teams often had difficulty transmitting reports to DCC and receiving orders from the DCO. Attack Team Leaders also had periodic difficulty transmitting and receiving information from the Repair 2 Casualty Coordinator.

A hand-held device similar to a Palm-Pilot™ could be an effective means to disseminate DC information during a casualty event if the supporting RF network is damage-resilient and provides effective coverage during the maximum state of material readiness, Condition ZEBRA. This technology would enable the BDAT (investigation teams) and Repair Party personnel to interface directly with the SCS, providing improved communication capabilities throughout the DC organization.

10.8 DC-ARM 45-man DC Organization and Response Strategy

The FY01 DC-ARM test series demonstrated that the DC manpower requirements on a modern destroyer-type ship could be significantly reduced from its present manning level of 105 to 45 people, with the proper integration of DC system automation and improved DC doctrine (organization and procedures). The DC-ARM 45-man DC organization presented in Section 3.2 provides the Navy with the first reduced DC manning approach that will support an orderly transition process to changing operational readiness conditions, an ability to respond to multiple/ simultaneous casualties, and ensures the DC Teams availability for 24 hours a day throughout a ship’s deployment. DC organization lessons learned during the DC-ARM FY 01 demonstration include:

- The six-man RRT easily handled all peacetime fire events. In most instances, the EWFD system and SCS technologies enabled the RRT primary responders to correct the casualty before the automated fire suppression system was needed. It was noted that it was more effective for the RRT Scene Leader to respond immediately with the primary responders rather than waiting to don breathing protection and respond with the RRT back-up attack/ overhaul team.

- The DC Console Operator in DCC during Condition I proved valuable for monitoring the DC system operations, conveying the directed commands of the DCO and maintaining a communication link to the Repair Stations.

- The DC Communicator/ Plotter in DCC during Condition I proved valuable for inputting the human-generated reports into the SCS and maintaining a communication link from the BDAT. This position could be eliminated if wearable computers and a reliable RF link were made available to the BDAT.

- The SCS provided good situation awareness and enabled the DCO to efficiently direct BDAT operations. The SCS prehit damage prediction provided a useful tool for prioritizing and planning the initial damage investigation.

- A minimum of four 2-man investigation teams are required for effective total ship coverage. Additional teams may be required if machinery spaces are unmanned during Condition I.

- A minimum of three 4-man back-up Attack Teams for each Repair Station are required to conduct simultaneous flooding and fire-fighting operations.

- One 3-man Support Team is required for each Repair Station to facilitate forcible entry operations, personnel casualty assistance, and to augment any system degradation resulting from battle damage (i.e., boundary maintenance, smoke control, and dewatering).

The determined 45-man DC organization assumes that DC-ARM-like technologies are available and is considered sufficient to support any supplemental DC actions, such as flight operations, CBR-D defense, body extraction, rig casualty power, and repair ship structures. This reduced DC manning approach should be considered for the DDG 51 and DD (X) programs.

10.9 Fleet Fire-Fighting and Damage Control Doctrine Evaluations – Historical Review

Over the past 10 years, a number of Fleet Doctrine Evaluation tests have been performed on the ex-USS *Shadwell*. They have demonstrated various damage control systems and technologies, identified training requirements for Navy personnel, and improved Navy doctrine associated with fire fighting. To assess the progress achieved in damage control improvements, past test results were reviewed and compared to the DC-ARM results. Table 11 summarizes six representative tests, three of which are from the DC-ARM program. The culminating test from each series was selected. The objectives of each test, the number of damage control personnel used, and the times to perform critical DC functions (e.g., setting fire boundaries, performing indirect/direct attacks, controlling the PDA) are summarized. Appendix O provides additional details on each test and on issues such as manpower, technology, and doctrine, as they relate to each test series. This appendix also includes a listing of key recommendations made during each test.

By any measure, a dramatic and significant improvement in DC capabilities has been achieved through the use of improved technologies and the DC-ARM approach. While the absolute number of personnel used in testing has remained relatively constant (17 to 27 persons), the ability to contain and control larger events involving more area on a greater number of threats dramatically increased. Consider that in the first FDE test, 20 personnel were required to contain a two-deck fire area of 73 m^2 (784 ft^2), four horizontal boundaries measuring 42 m^2 (448 ft^2) total, and one vertical boundary measuring 36 m^2 (392 ft^2). In the final DC-ARM test, slightly more personnel (24) were able to contain and control a much larger event in slightly less time. A four-deck fire area of 200 m^2 (2150 ft^2) was controlled in FY01, with 4 vertical boundaries (including boundaries above sympathetically ignited fires) totaling 203 m^2 (2180 ft^2) and 10 horizontal boundaries totaling 195 m^2 (2090 ft^2). On a per-area basis, much less manpower was needed in the DC-ARM evolution to achieve equivalent containment and control performance compared to pre-DC-ARM evolutions. This is shown graphically in Fig. 46.

By all measures, the relative performance of personnel and systems was actually not equivalent but much greater than that achieved in pre-DC-ARM tests. Fire main ruptures, absent from earlier tests, were introduced in the DC-ARM testing. In all DC-ARM tests, tenability in access passageways around the damage area was maintained. This was not the case in earlier tests.

Table 11 — Summary of ex-USS *Shadwell* Fleet Fire Fighting and Fleet Doctrine Evaluation Tests

	Test Series (Date)	Goals and Objectives	Damage Control Organization			Compartments Involved					Critical Times (minutes)				
			DCC	Repair Parties (persons)	Total # of Personnel	Fire Location	Fire Description	Total Area of Fire Compartments	Boundaries	Fire Main Rupture	Tenability in P-ways	Fire Main Rupture Secured	Boundaries Set	Control PDA	Extinguish/ Secure PDA
Historical Test Series - Pre-DC-Arm	Fleet Doctrine Evaluation (FDE) Tests (1991)	Evaluate containment strategies for major conflagrations	DCA and Phone Talker	• Repair 4 - (8) • Attack Team 1 - (2) • Attack Team 2 - (5) • Boundary Team - (3)	20	Berthing 2 RICER 2	11 MW spray fire Three Class A wood cribs	73 m^2 (784 ft^2)	(1) vertical boundary (4) horizontal boundaries	No	Not maintained in RICER 1 until PDA controlled	N/A			
Historical Test Series - Pre-DC-Arm	Heat and Smoke Management Tests (1992)	Evaluate smoke and heat management	CDO, EDO, and OOD	• In-port RRT • In-port Emergency Team (IET) Attack & Desmoking Teams	20 (approx.)	Fwd CIC CIC Office	Diesel & heptane Class A wood crib	45 m^2 (479 ft^2)	(1) vertical boundary (4) horizontal boundaries	No	Not maintained until desmoking evolution	N/A			
Historical Test Series - Pre-DC-Arm	Firefighting & Doctrine Control Equipment Evaluation Tests (1996)	Evaluate SCBA		• Repair Party - (16)	17	Berthing 2 Storage	Class A wood cribs (5 total)	127 m^2 (1372 ft^2)	(1) vertical boundary (7) horizontal boundaries	No				42 (approx.)	50 (approx.)
DC-ARM Test Series	DC-ARM (1998)	Baseline evaluation of current capabilities and technologies	DCA and Console Operator	• RRT - (10) • Repair Party - (15)	27	Comm Center	Two Class A wood cribs	113 m^2 (1219 ft^2)	(2) vertical boundaries (9) horizontal boundaries	Yes					
DC-ARM Test Series	DC-ARM (2000)	Evaluate new systems & technologies used in a remote-manual mode to reduce manning	DCA and 3 Support Personnel	• RRT - (8) • Back-Up Support Team (9)	21	Comm Center Radio Transmitter	Spray fires and wood crib	200 m^2 (2150 ft^2)	(4) vertical boundaries (10) horizontal boundaries	Yes			2 — water mist 7 — men	38	
DC-ARM Test Series	DC-ARM (2001)	Evaluate refined damage control systems.	DCO and 2 Support Personnel	• Repair Party — (17)	24	Comm Center Radio Transmitter	Spray fires and wood crib	200 m^2 (2150 ft^2)	(4) vertical boundaries (10) horizontal boundaries	Yes			1 — water mist 8.5 — men	32	

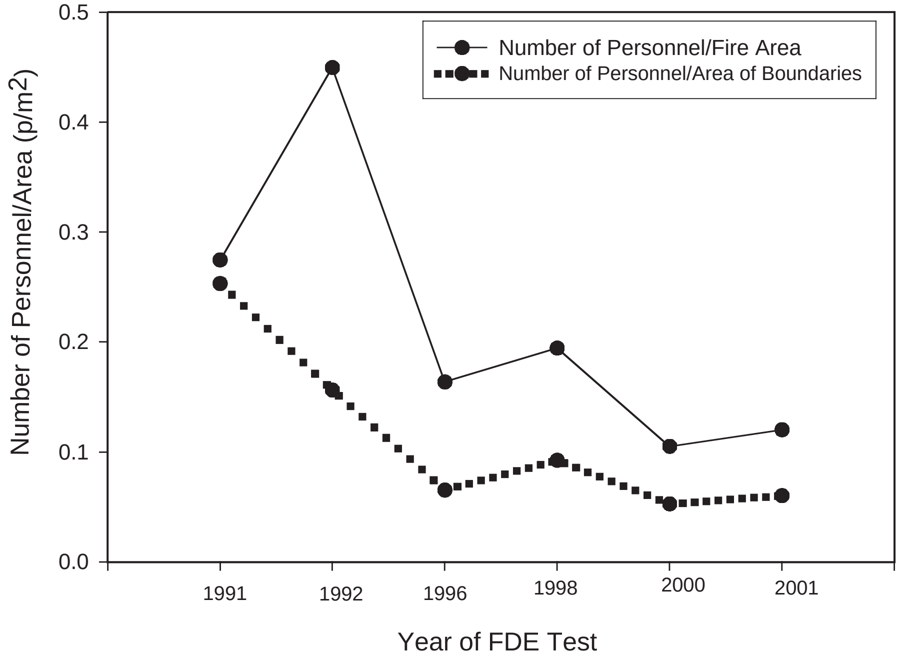


Fig. 46 — Comparison of personnel required to contain damage in FDE tests

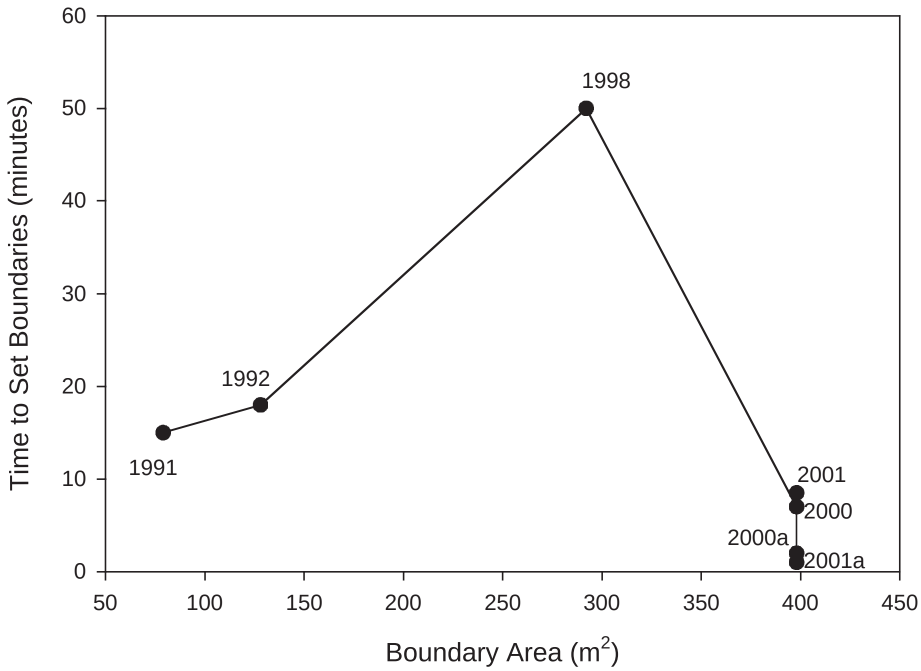
The impact of installed systems and automation is evident in a comparison of the three DC-ARM test series. FY 98 represented a baseline of existing conditions, with the involved area and number of threats increased compared to previous testing. As expected, more personnel were required to contain and control the damage over a longer time period compared to pre-DC-ARM tests involving lesser threats. Performance dramatically improved with the introduction of remote-manual and fully automated systems. This is shown graphically in Fig. 47, which compares the number of boundaries and resulting time for boundary setting for the various tests.

11. CONCLUSIONS

11.1 General

1. The FY 01 DC-ARM test series demonstrated that effective fire protection and damage control can be accomplished with reduced manning through the use of installed systems monitored and operated through a supervisory control system. While all of the systems have yet to be fully developed (i.e., achieve complete, autonomous control), the benefits gained have been quantitatively demonstrated. Most systems have been developed to the point where the ship platforms can implement the technologies and associated manning structures. The systems have sufficient flexibility to allow for refinements in hardware and control system performance. The DC-ARM SCS is the *onl*y Navy DC information and control system that has been tested and evaluated in a realistic shipboard damage environment. **The systems and approaches demonstrated in DC-ARM can be implemented today to reduce damage control manning requirements.**

2. With the assistance of the automated DC systems, the DC organization was more effective during wartime casualties (i.e., “more severe”) compared to FY98 and FY00. Fewer people were required because automated systems accomplished tasks that were performed manually in FY98 (i.e.,



Note — Times shown to set boundaries using men for all points except 2000a and 2001a, which show times to set boundaries automatically using the water mist system.

Fig. 47 — Comparison of boundary setting performance in FDE tests

isolation of fire main rupture, desmoking, and setting fire boundaries). In general, the actions were completed more quickly by using the automated DC systems.

3. The advance of Fleet Doctrine Evaluation tests through the FY 01 DC-ARM test series has shown a quantifiable improvement in capability with simultaneous reduction in manpower. Over the past 10 years, the area, the number of involved compartments and associated fire boundaries, and the severity of the fire threats have significantly increased. Despite the larger areas and more severe threats, the net number of damage control personnel needed to manage these threats has decreased as a result of improved situational awareness and installed systems.

To fully implement the DC-ARM approach, automatic isolation of other mechanical and electrical systems must be developed. Otherwise, additional DC personnel will be required to perform tasks related to damage recovery of these systems.

11.2 DC-ARM Demonstration Process

The DC-ARM program demonstrated DC manning and performance with the following stages of technology applied:

1. Baseline Demonstration: Improved doctrine and existing technology aboard Navy ships.
2. Remote Manual Control Demonstrations: Remote manual control of key systems and improved instrumentation and information systems to enable improved situation awareness.
3. Automated Demonstration: Automated responses to damage, where practical, integrated with complementary manual actions.

These staged demonstrations provide the Navy with benchmarks of technology risk, DC manning, and DC performance that can be used to determine the balance that best suits a particular program for upgrading existing ships or for designing new ships.

11.3 Supervisory Control System

1. The SCS was effective in monitoring sensors, operating systems, and providing guidance to the DCO (e.g., when to send personnel and when to operate the smoke injection system). This type of technology and capability is considered essential for future optimally manned combatants.

2. For the most part, the SCS correctly identified the primary damage area. In some instances, a fully developed fire was identified in areas outside the PDA. This was a result of interpretation of data, which was set by the test team to be intentionally faulty. Further refinement of the filtering methodology is possible provided a study is conducted to quantify the actual effects of blast damage on sensor and control networks.

3. The DC-ARM SCS development program defined and applied a design methodology development of DC information systems that will enable successful application of DC-ARM-like technology to a specific ship design [36].

4. The SCS Surveillance Video was extremely effective for improving situation awareness and complements the other SCS control and display functions.

11.4 Other Systems/Equipment

1. Water Mist

   a. The water mist system, which was automatically operated by the SCS, was effective for controlling fires in APDA compartments. Fire boundaries were set more quickly using the automated water mist system than manually. Although the water mist system did not always prevent sympathetic ignition in the APDA compartments, the performance goals were achieved.

   b. Additional testing is required to optimize the water mist system for the boundary cooling mode.

   c. Isolation of ruptured water mist systems has not been performed. An approach somewhat different than fire main isolation has been proposed.

2. Smart Valve Technology

   a. The fire main Smart Valves provided a good alternative to manual rupture isolation. In the wartime demonstrations, fire main ruptures were automatically detected and isolated by the SCS. Unusable fireplugs, due to fire main ruptures, were also identified by the SCS. In most cases, this allowed manual boundaries to be set quickly as time was not wasted using out-of-service fireplugs.

   b. Performance differences between the fire main control system operated by the SCS and operated locally (autonomous, reflexive) have not been well quantified in large-scale demonstration.

   c. Smart Valve technology is considered essential for future optimally manned combatants.

3. Early Warning Fire Detection (EWFD)

   a. All peacetime fires were accurately identified by the EWFD. In terms of fire detection, the EWFD outperformed the COTS detectors, both in ability to detect a fire and in identifying a fire earlier. In some cases, the differences were substantial, particularly where the COTS detectors failed to alarm in a fire event.

   b. The ability of the EWFD system to screen out most, if not all, plausible nuisance sources, demonstrated in previous EWFD test series [24-33], was not verified in these demonstrations. While the EWFD showed improved performance for actual fires compared to COTS detectors, the ability to screen nuisance sources in these demonstrations was essentially the same for all of the detectors. Improved nuisance screening by the EWFD system is a highly desirable attribute and had been demonstrated in previous tests; the problems encountered in these demonstrations should be addressed.

4. Smoke Ejection System (SES)

   a. The smoke ejection system was effective for maintaining visibility in the second deck and main deck passageways. Although this system was operated in the remote-manual mode (i.e., DCO required to activate system), SES was able to effectively reduce the manpower requirements compared to manual desmoking.

   b. Recommendations to activate the SES were based on optical density meter measurements, which may not be suitable for shipboard installation because of the size of these devices.

5. Communications – communications continued to present problems for the DC teams, resulting in repeated or lost reports/orders.

12. RECOMMENDATIONS

1. The DC-ARM approach and philosophy should be implemented in the design of new ship platforms, including DD(X), CVN(21), T-AKE, and LHA(R).

   a. Automated systems, including water mist, fire main and water mist rupture control, early warning and damage control sensing, compartment video, and smoke control should be included in the new damage control design.

   b. A minimum of four 2-person investigative teams (BDAT) is required for effective total ship coverage. Additional teams may be required if machinery spaces are unmanned during Condition I.

   c. A minimum of three 4-person Attack Teams is required for each Repair Station to conduct simultaneous fire-fighting and flooding operations.

   d. A minimum of one 3-person Support Team is required for each Repair Station to assist with access/forcible entry operations, personnel casualty assistance, and system degradation resulting from battle damage.

2. Refinements of the DC-ARM systems should focus on autonomous (local) control of systems and tradeoffs between hierarchical, intermediate, and local controls.

3. Automatic isolation of other HM&E systems (particularly mechanical and electrical systems) should be developed to complement the DC-ARM approach.

4. An enhanced simulator should be developed for use in exercising SCS systems in the absence of large-scale tests. This simulator, combined with additional fire testing of advanced hardware, should be used to refine algorithms and decision aids related to the following:

   a. Identification of the PDA;

   b. Identification of fires outside the PDA and characterization of their growth;

   c. System performance differences with and without prehit algorithms;

   d. Identification of fires and damage with mixed "good" and "bad" data;

   e. Optimization of the Task Management Module used in the current SCS; and

   f. Overall reliability and operability of the system to prevent system lock-ups observed in some of the tests.

5. Refined DC-ARM SCS and subsystems should be developed and tested to investigate performance parameters related to the following:

   a. Different levels of SCS hierarchical control (local/autonomous, deck/zone, and DCC), including associated doctrine and tactics;

   b. Water mist rupture control, boundary cooling optimization, and effectiveness of partially intact systems in the PDA; and

   c. Automated smoke control.

6. Verification tests of the EWFD should be performed to establish the level of nuisance alarm screening, with the goal of transitioning to commercial viability.

7. Improvements should be made to specific ex-*Shadwell* systems, including:

   a. Water mist solenoid valves to include valve position indication; and

   b. Improved video streaming to the SCS (i.e., Machine Vision technology).

8. Alternative methods/technologies to track smoke for smoke control system operation should be developed.

9. Improved DC communications should be developed. Consideration should be given to developing a communication system that provides transmission of information over the LAN via a hand-held device similar to a Palm-Pilot.™ At a minimum, all communication devices (i.e., SCBA voice amplifiers, hand-held radios, personnel monitors, and/or wearable computers) must be compatible and the supporting RF network must be reliable and damage resilient.

10. Development of a hybrid water mist system that can be used for electronic space fire protection.

11. Live-fire weapons effect testing (WET) should be expanded to include the use and evaluation of active DC systems in a live-fire WET environment.

12. Additional improvement in the Navy's live fire fire-fighting training is needed to enhance minimally manned DC response operations. At a minimum, the Fleet Training Centers should include hands-on experience with proper nozzle technique for direct and indirect attacks, forcible entry procedures, vertical entry, active use of ventilation, and demonstration of proper techniques for battle damage assessment. The practicability of conducting these exercises in a more realistic damage environment should also be considered and pursued.

13. Follow-on testing should be conducted to validate damage-resilient piping designs and the cooling effectiveness of water mist sprays in the PDA if discharged immediately following a weapon hit.

14. Water mist development should be continued and a suitable water-based delivery method identifed for electronic space fire protection.

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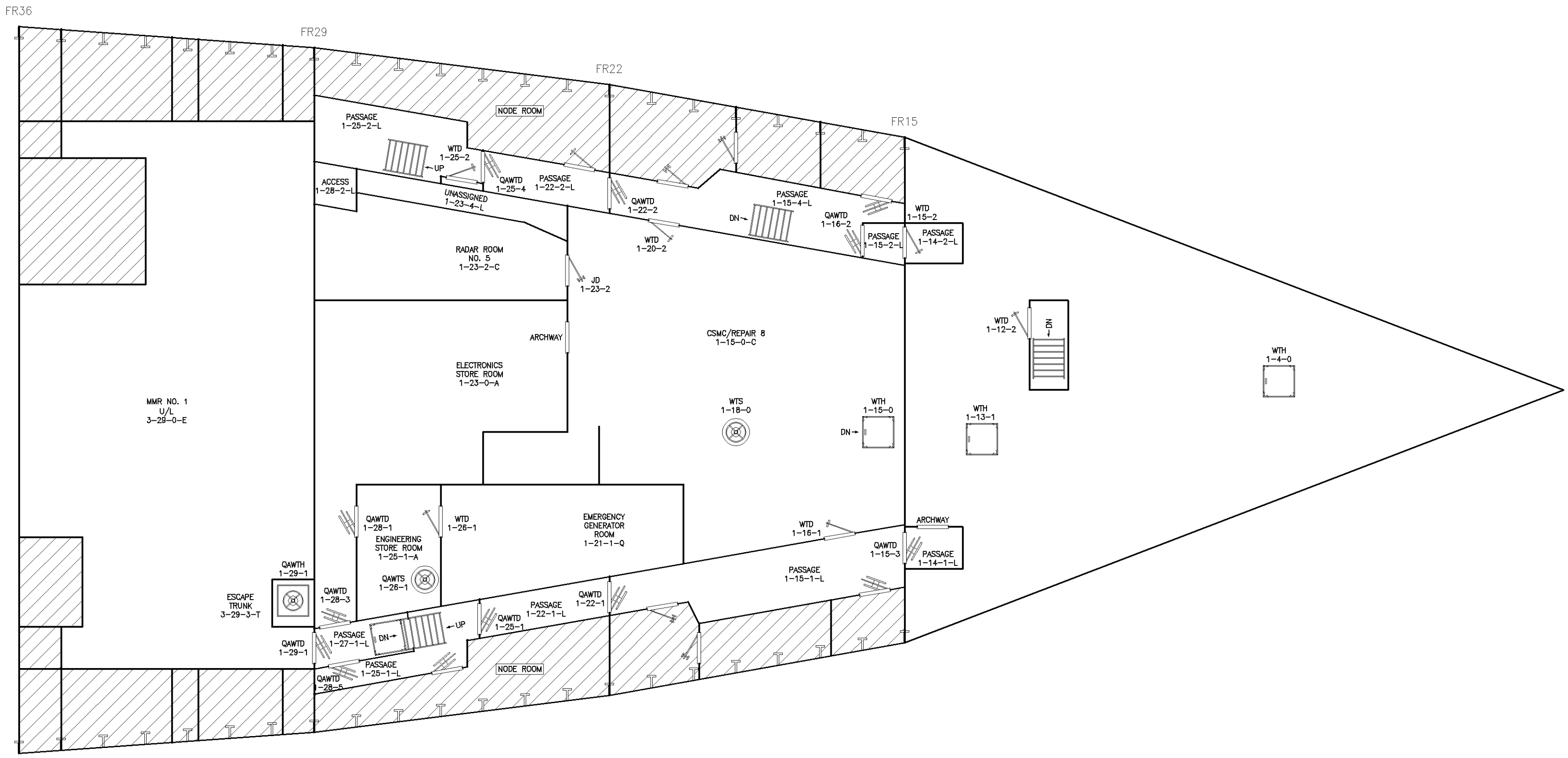
Appendix A

SHADWELL Layout with Safety Team Accesses Removed



NOTE:
HATCHED AREAS ARE NOT PART OF TEST AREA.

Fig. A1 – Layout of main deck with Safety Team accesses removed

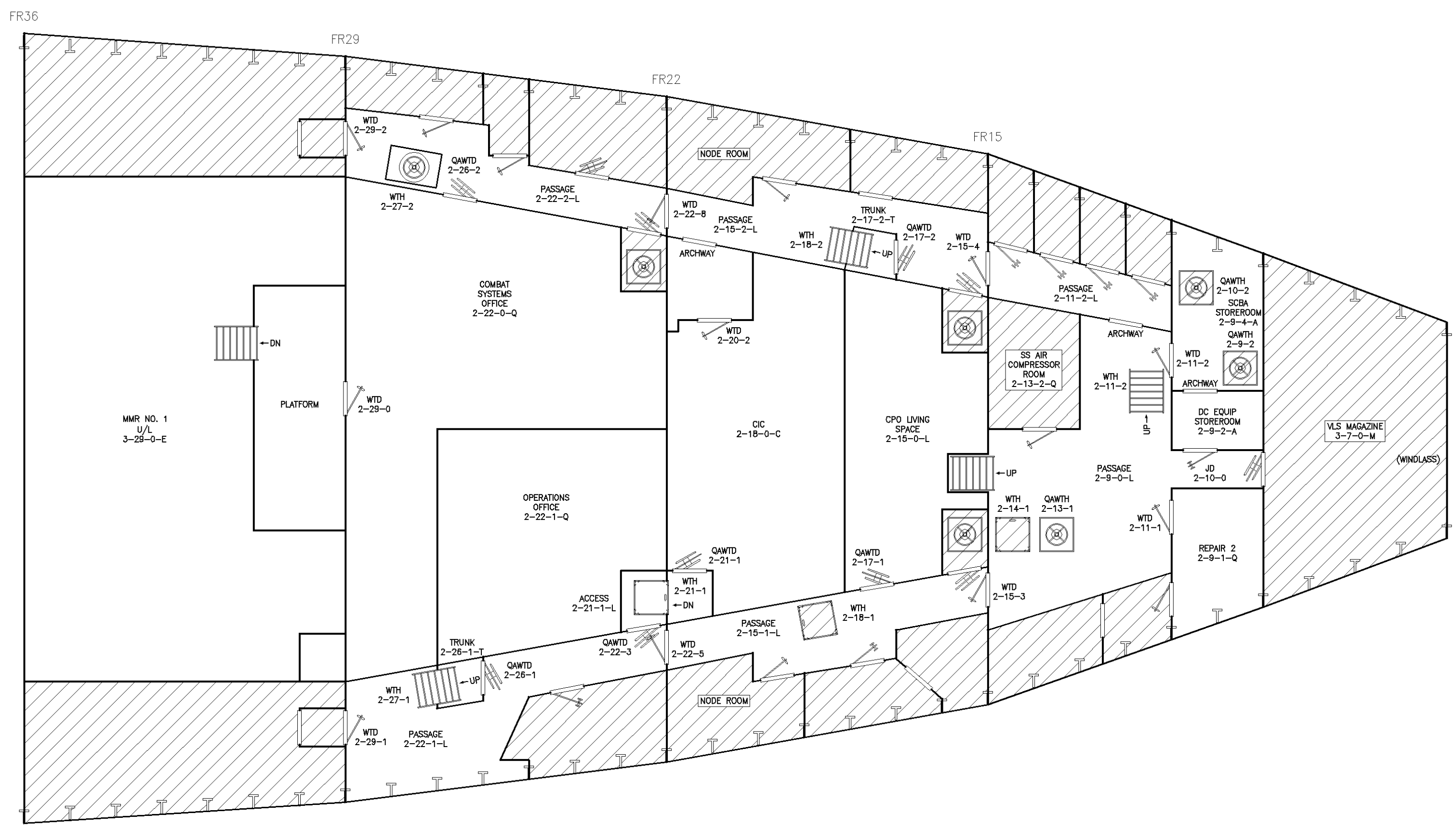


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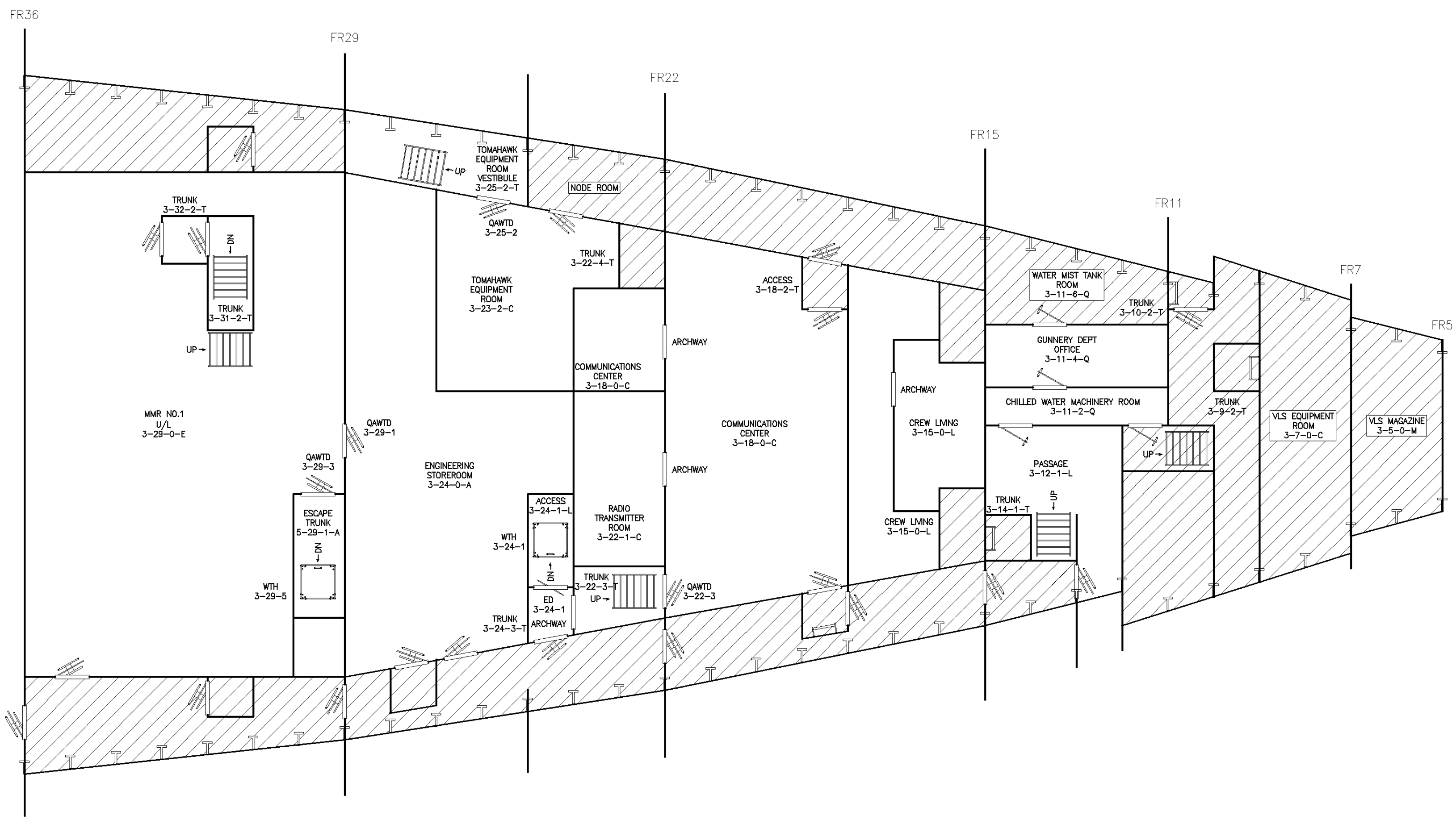
Fig. A2 – Layout of second deck with Safety Team accesses removed



NOTE:
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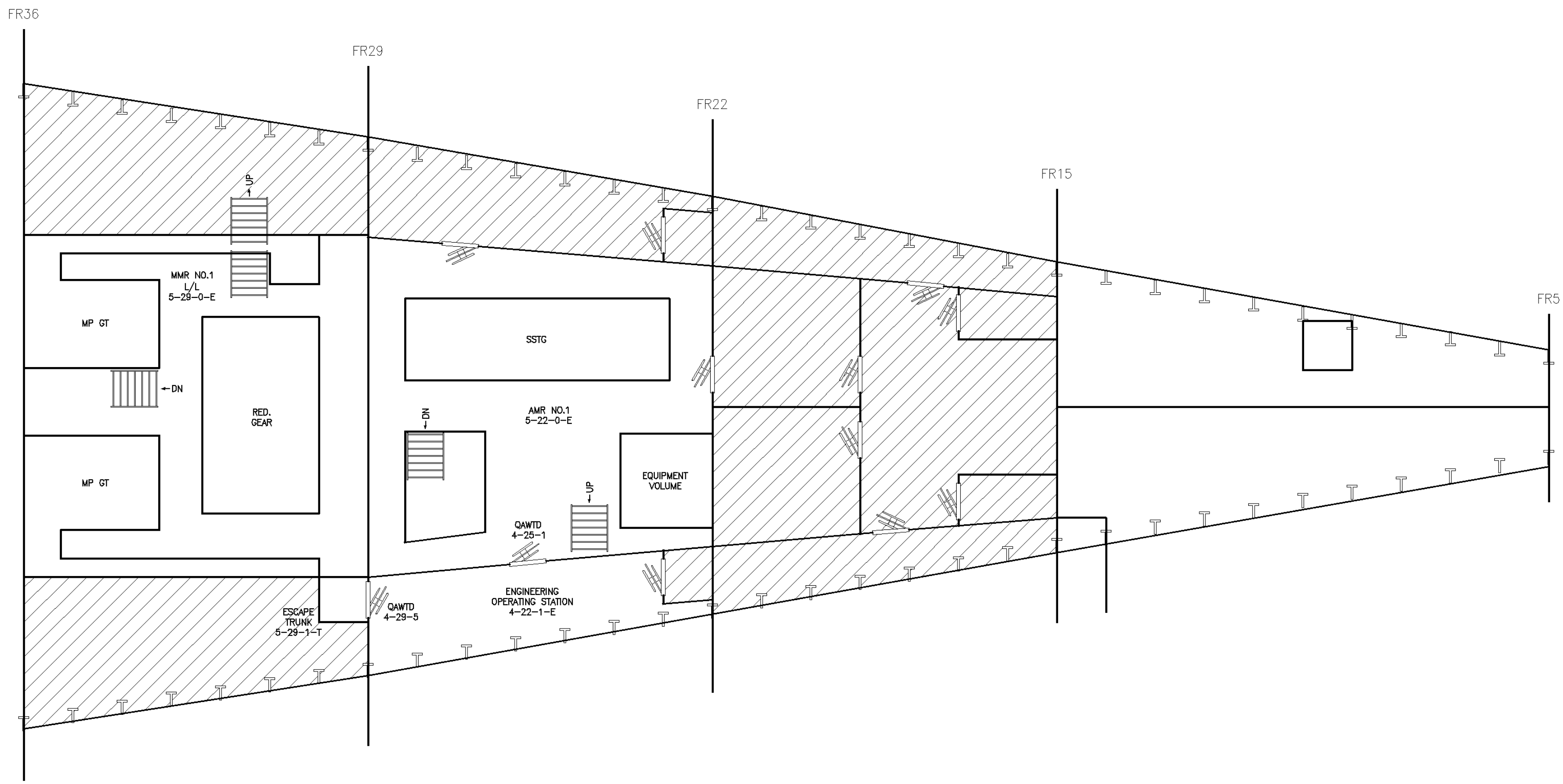
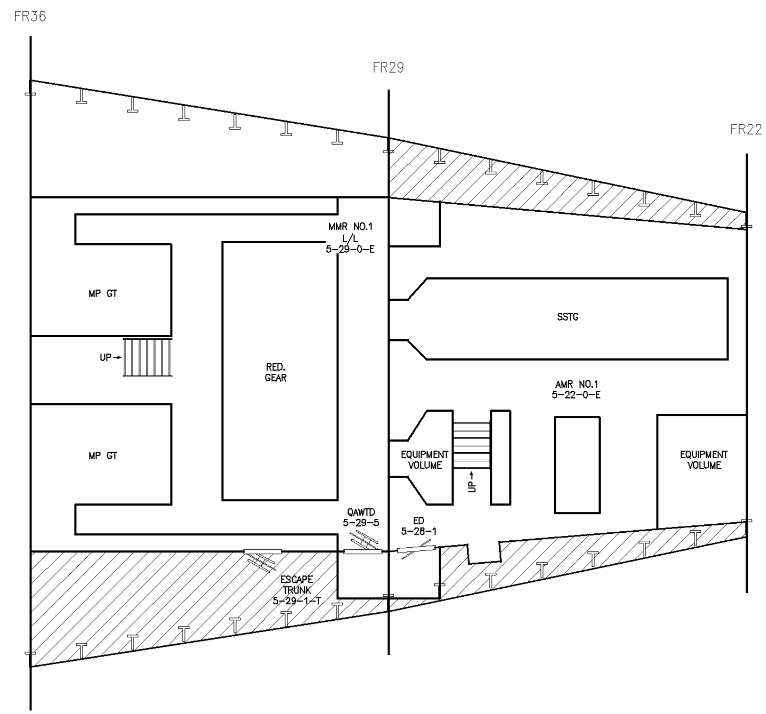
Fig. A3– Layout of third deck with Safety Team accesses removed



NOTE:
HATCHED AREAS ARE NOT PART OF TEST AREA.

Fig. A4 – Layout of fourth deck with Safety Team accesses removed



NOTE:
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Figure A5 – Layout of hold level with Safety Team accesses removed

Appendix B

Schematic of the Fire Main System

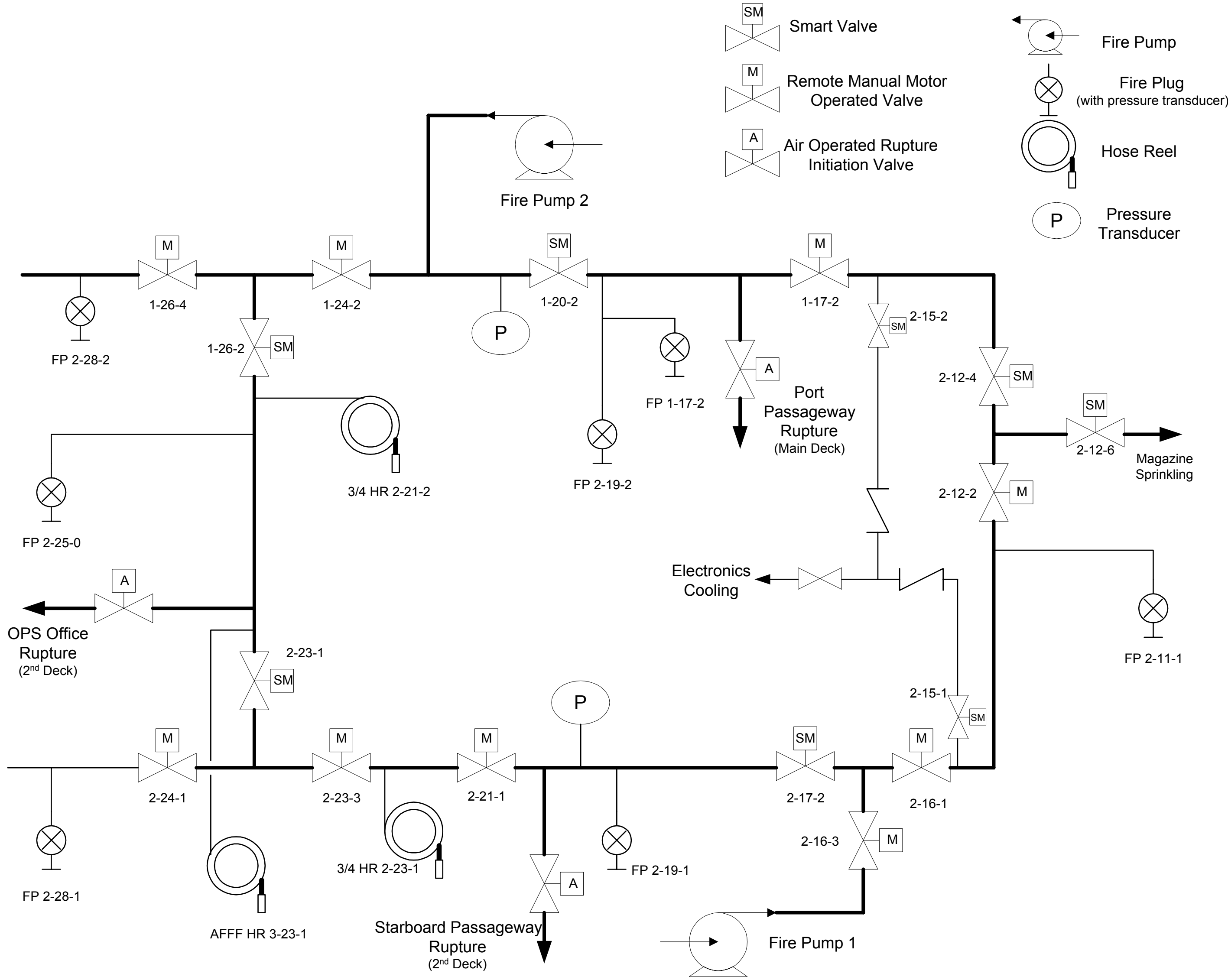


Fig. X1 – Schematic of the fire main

Appendix C

Schematics of Water Mist System

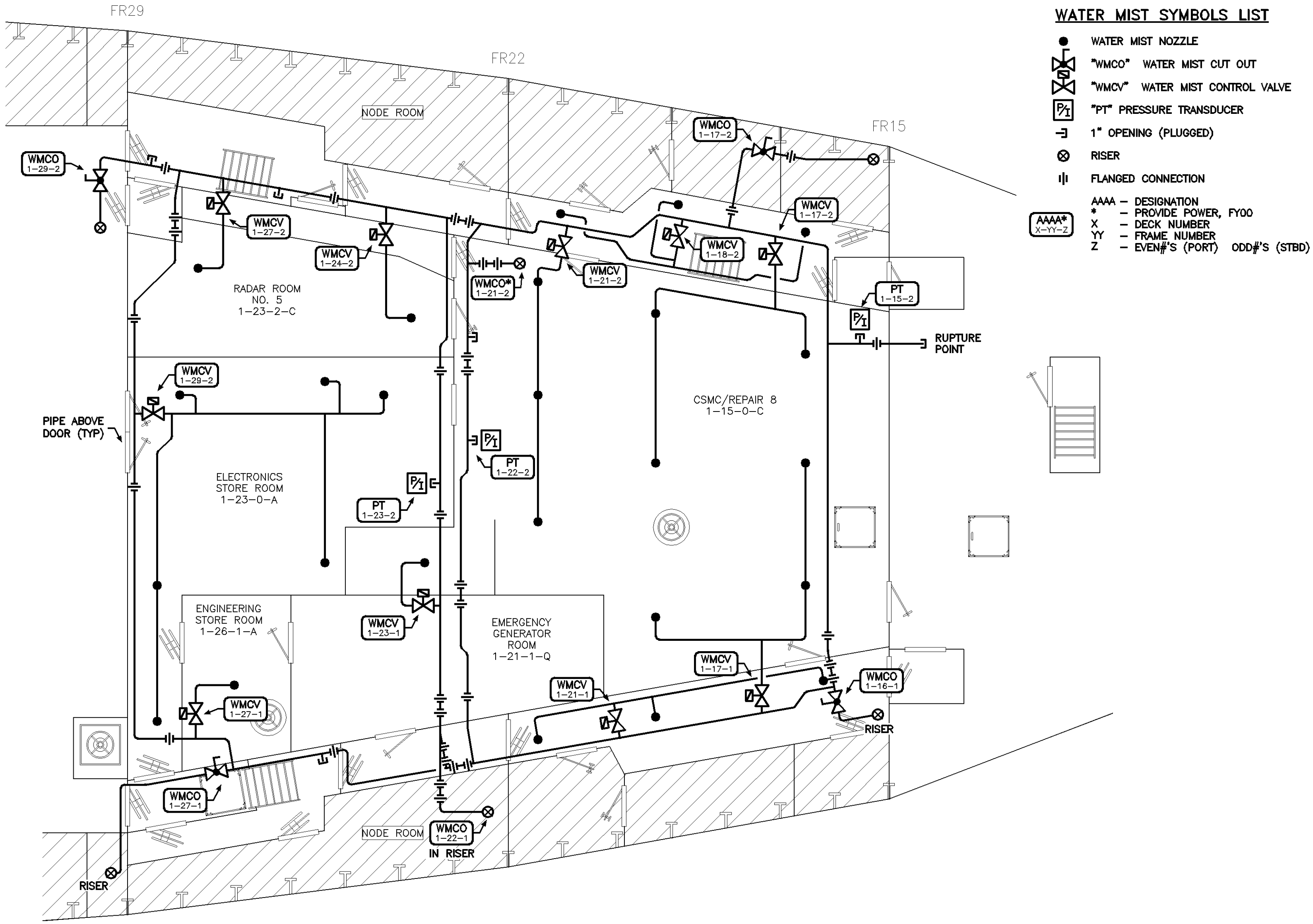


Fig. C1 – Water mist layout for main deck

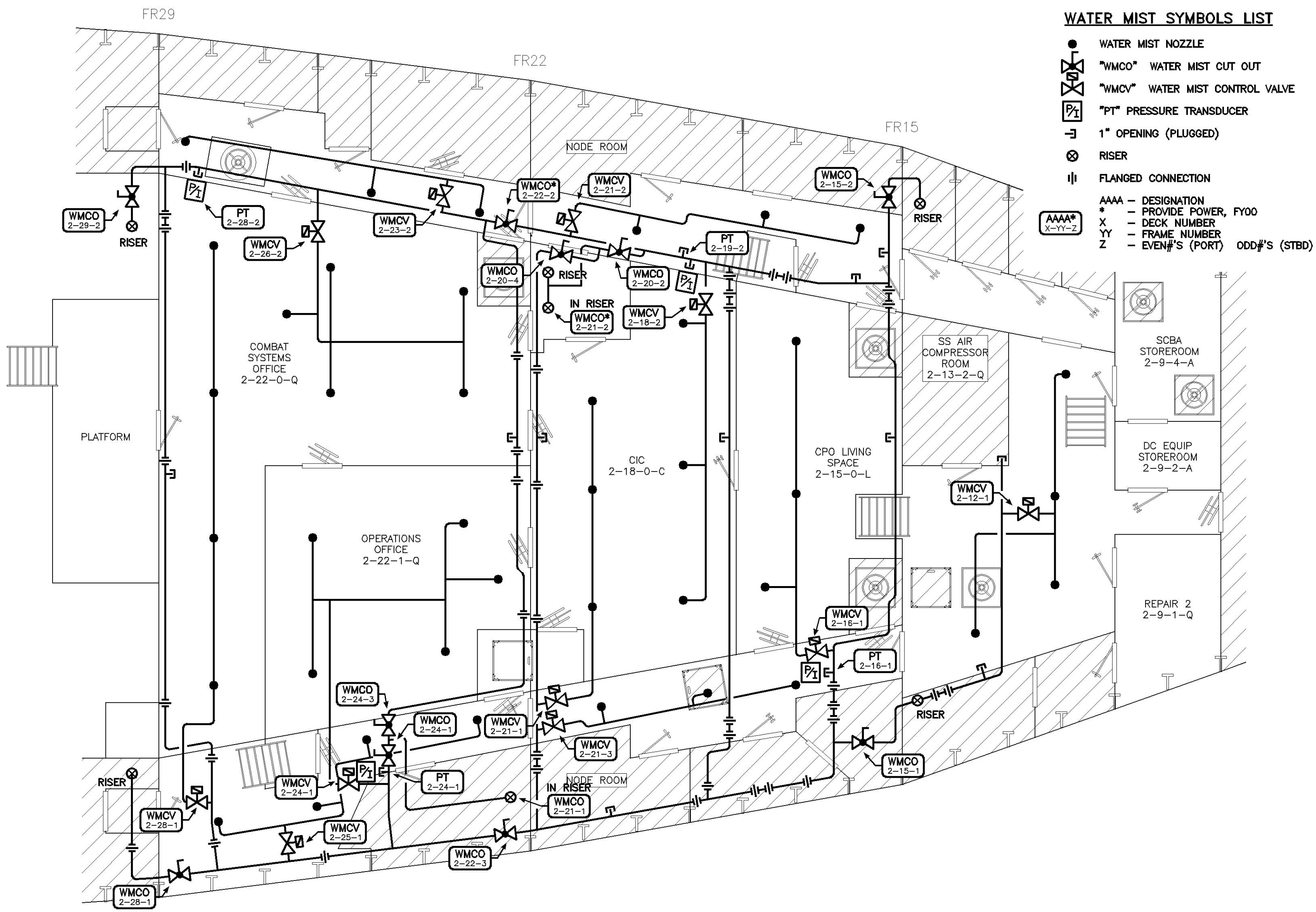


Fig. C2 – Water mist layout for second deck

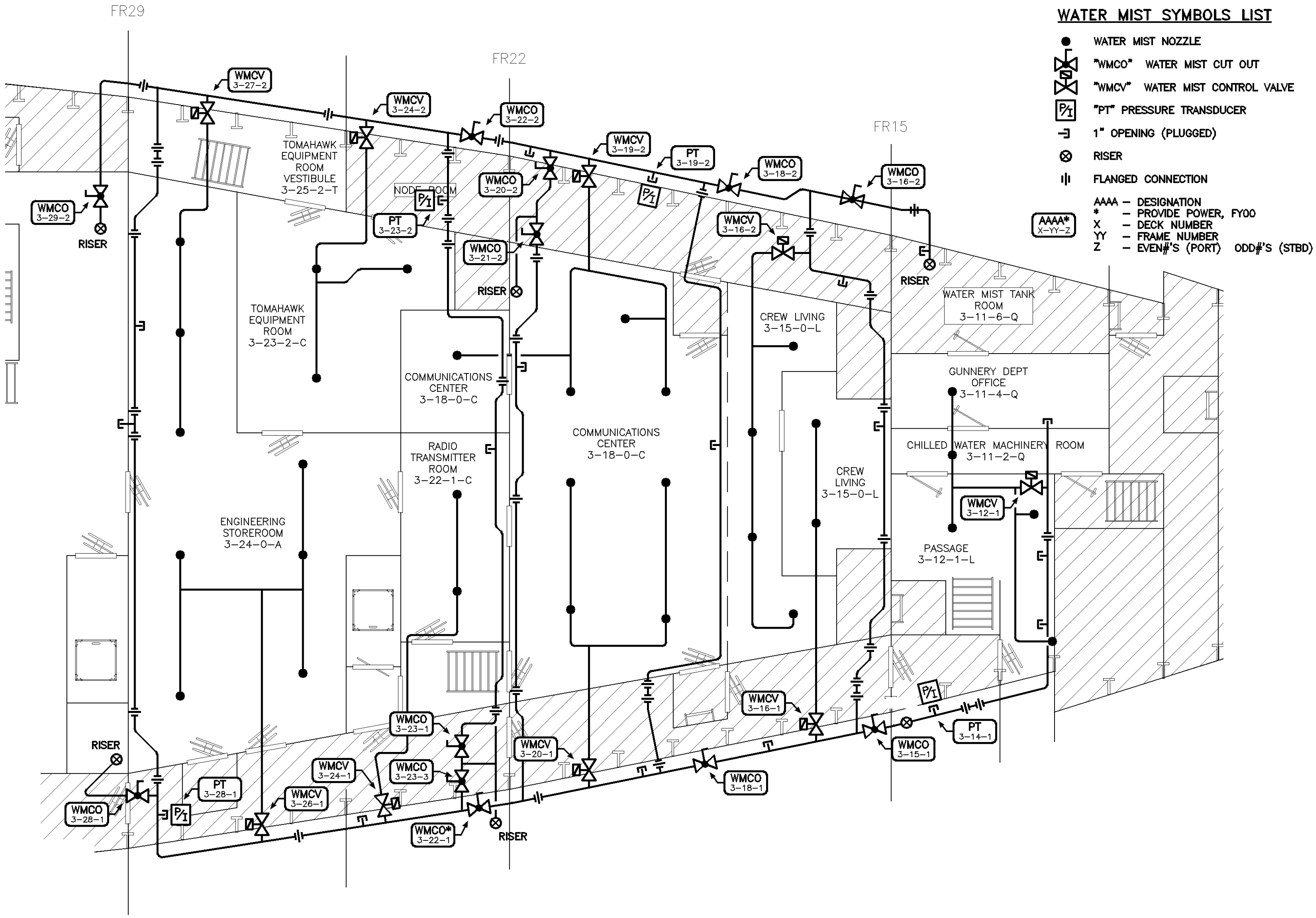


Fig. C3 – Water mist layout for third deck

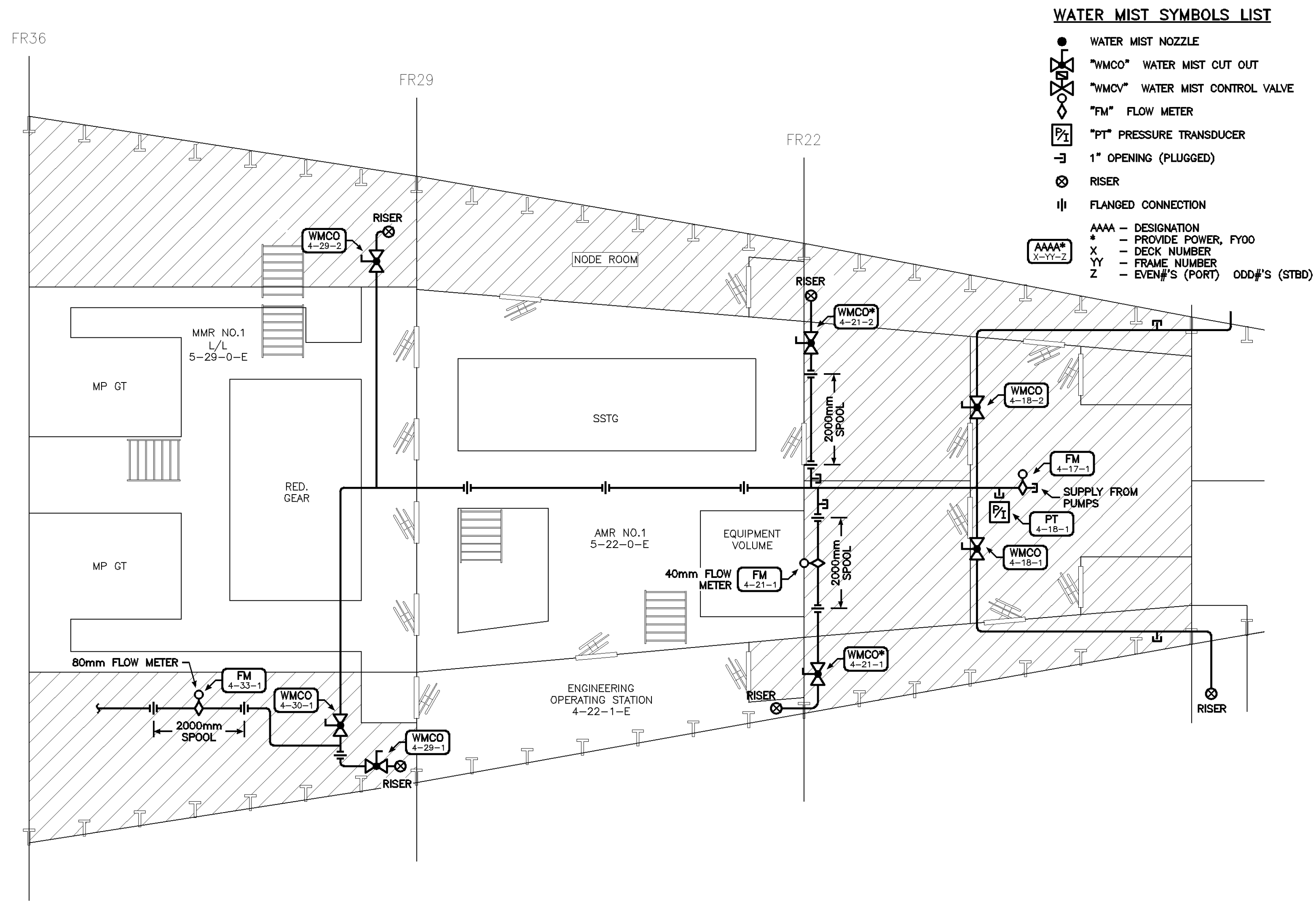


Fig. C4 – Water mist layout for fourth deck

Appendix D

SES Terminal Locations

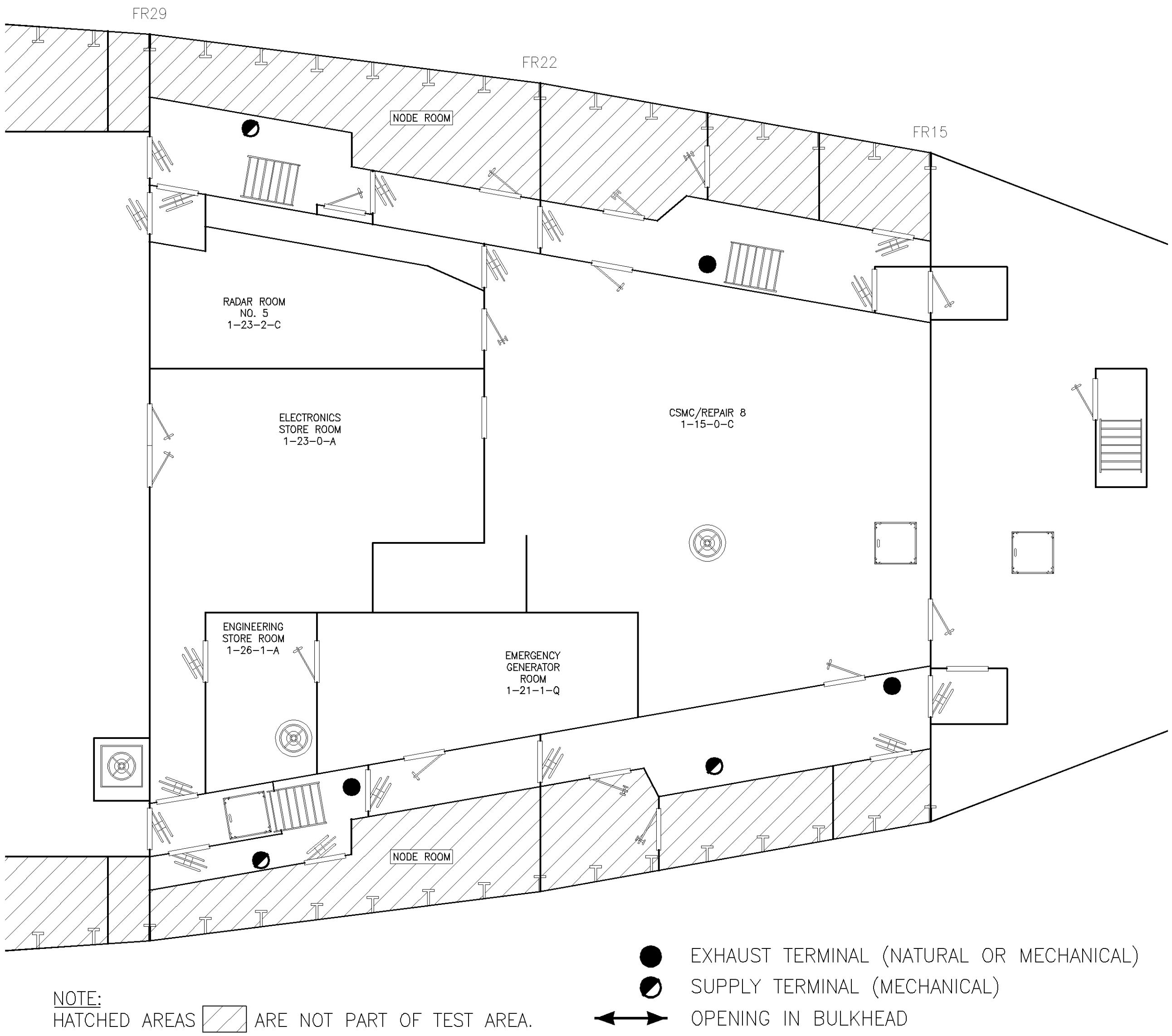


Fig. D1 – Main deck SES terminal layout

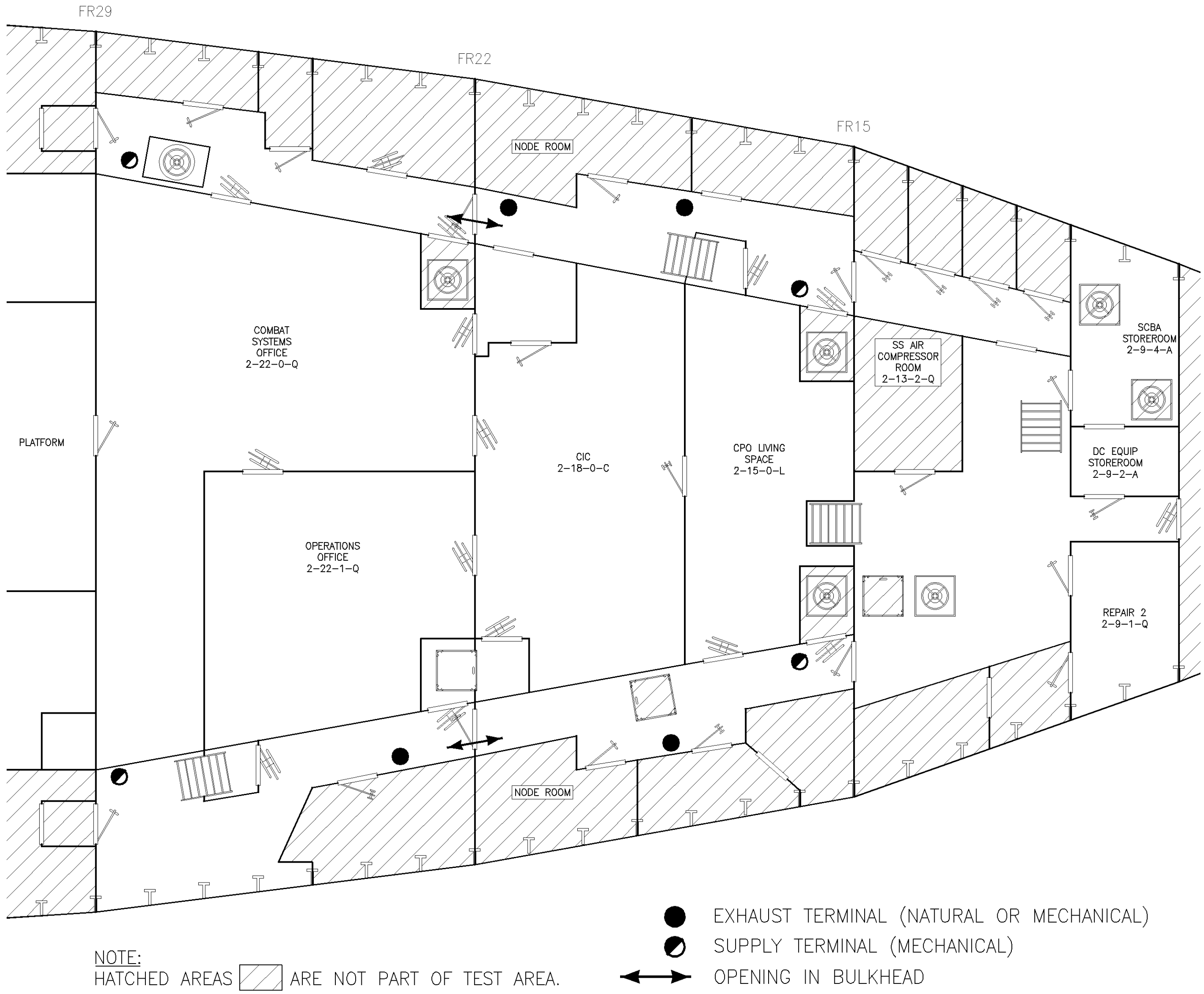


Fig. D2 – Second deck SES terminal layout

Appendix E

SHADWELL Sensor Locations

INSTRUMENTATION SYMBOLS LIST

G GAS (O_2, CO_2, AND CO) CONCENTRATION (% VOL.)

Td DECK THERMOCOUPLE (°C)

Th THERMOCOUPLE – HIGH (°C)

TL THERMOCOUPLE – LOW (°C)

Tb BULKHEAD THERMOCOUPLE (°C)

Tod OVERHEAD DECK THERMOCOUPLE (°C)

Tf FLAME THERMOCOUPLE (°C)

OD OPTICAL DENSITY METER (ODM) (%T)

P DIFFERENTIAL PRESSURE REFERENCED TO AMBIENT (IN WATER)

Pw FIRE MAIN PRESSURE (PSI)

Pf FUEL PRESSURE (PSI)

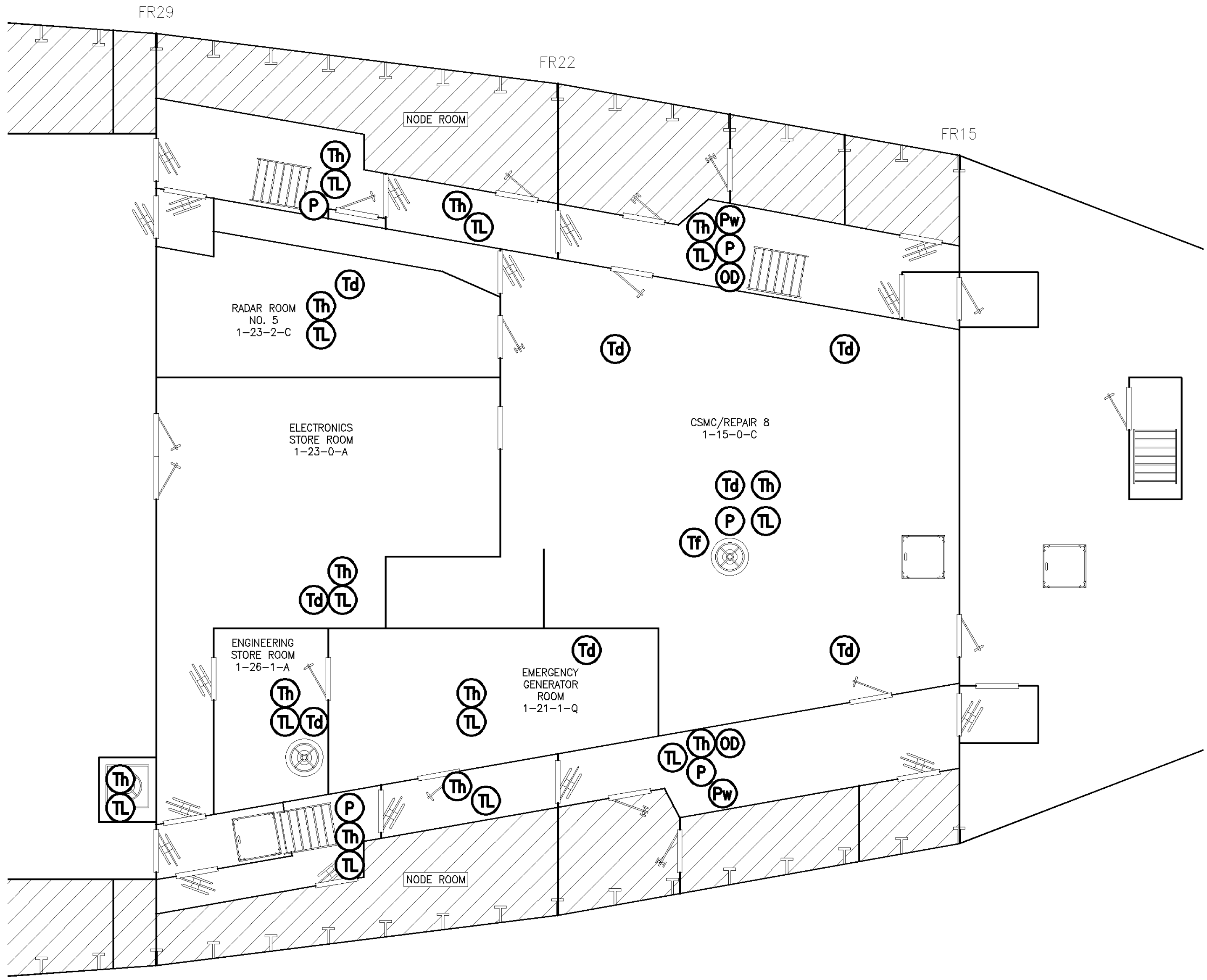
Ft FIRE MAIN FLOW METER (TURBINE) (GPM)

Fu FIRE MAIN FLOW METER (ULTRASONIC) (GPM)

C CALORIMETER (BTU/SQ.FT.)

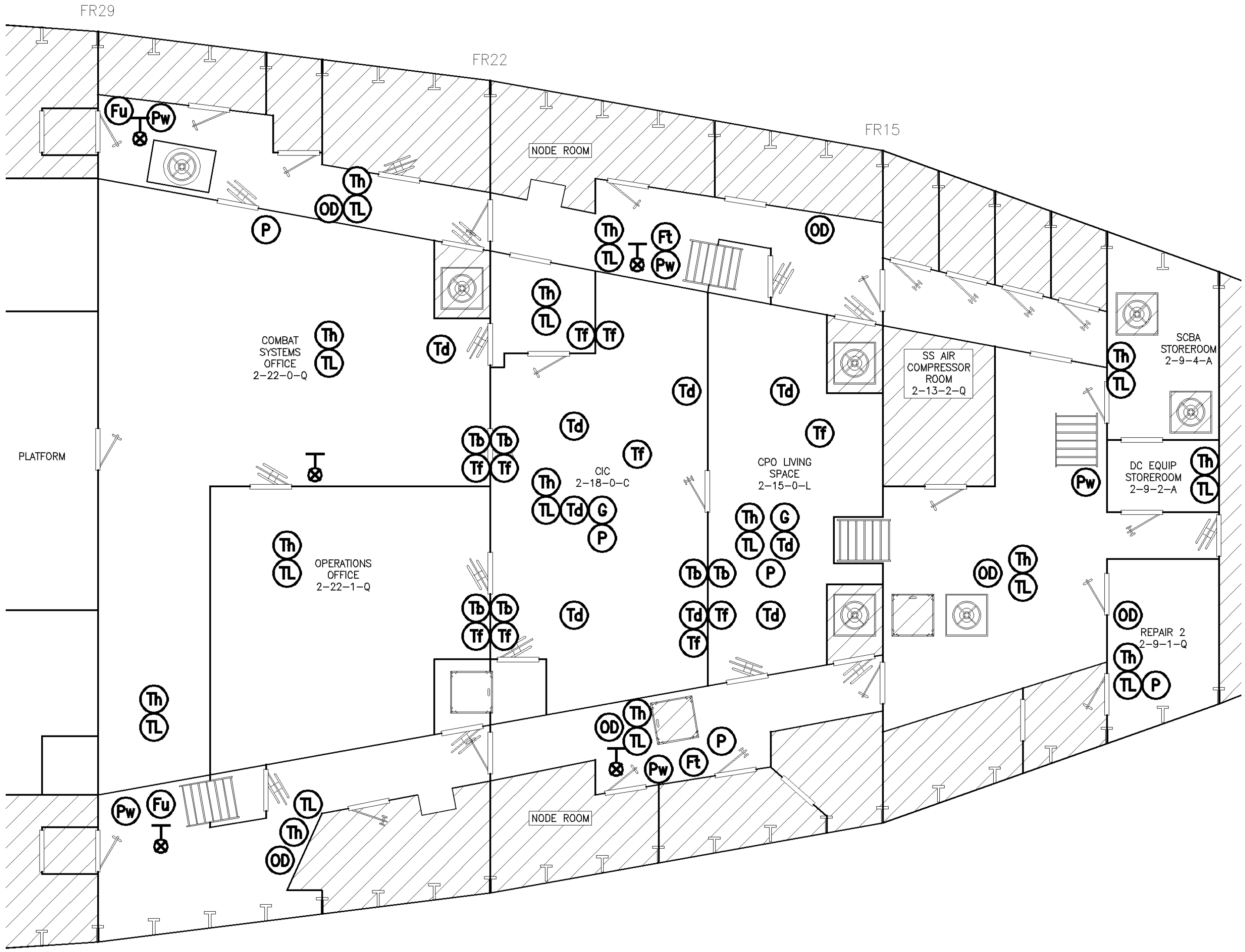
FIRE PLUG

Fig. E1 – Instrumentation key



NOTE:
HATCHED AREAS ARE NOT PART OF TEST AREA.

Fig. E2 - Main deck instrumentation layout



NOTE:
HATCHED AREAS ▨ ARE NOT PART OF TEST AREA.

Fig. E3 - Second deck instrumentation layout

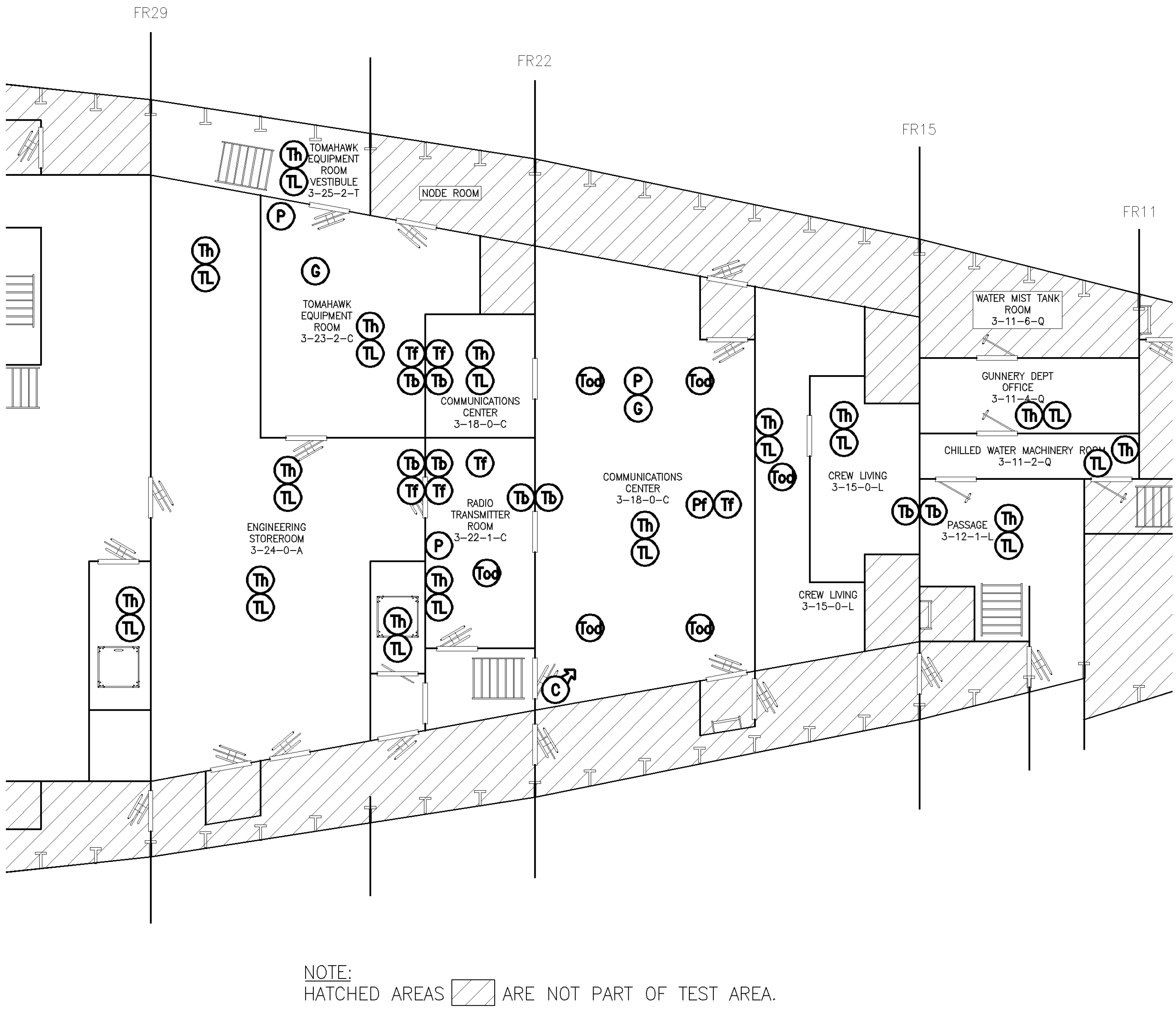


Fig. E4 – Third deck instrumentation layout

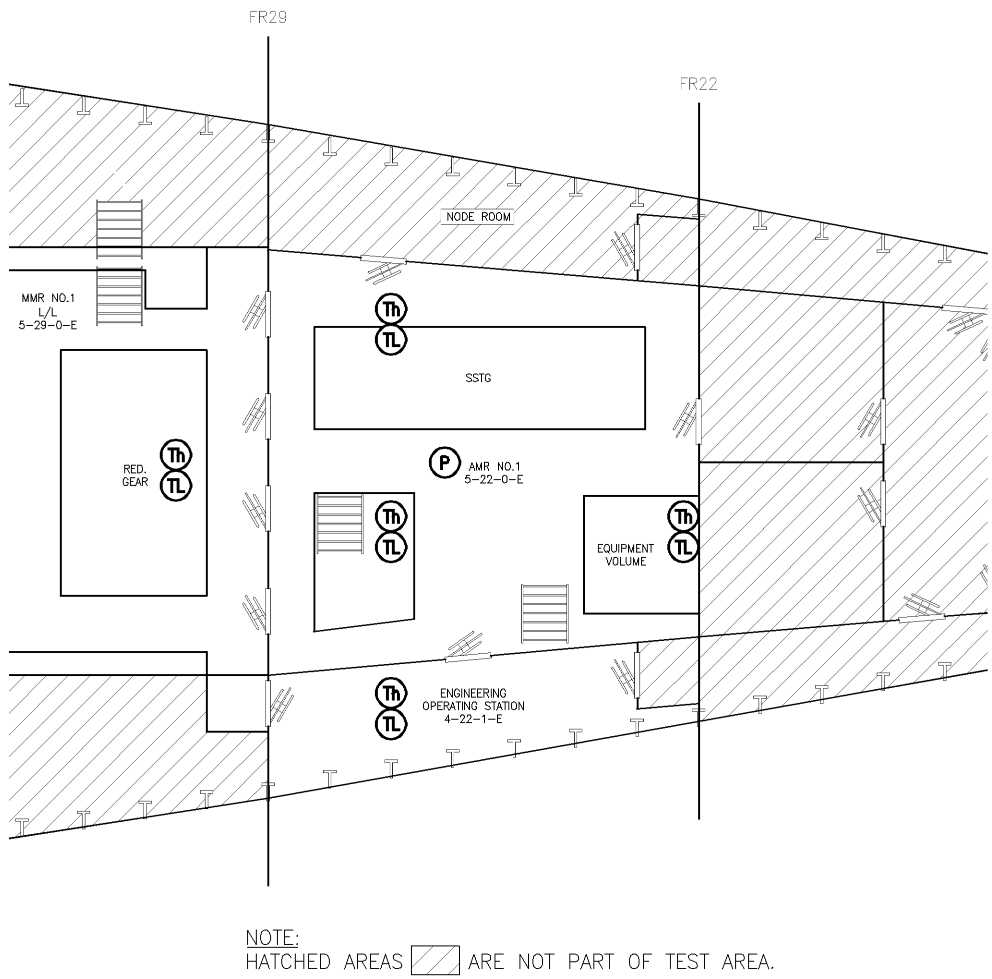
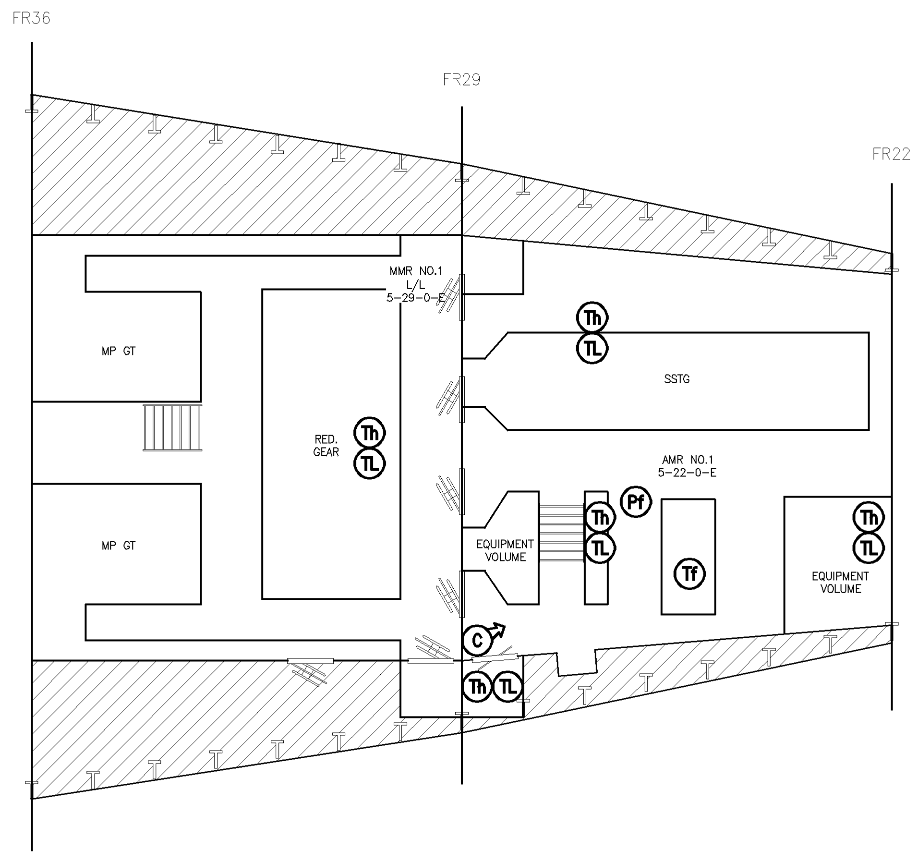


Fig. E5 – Fourth deck instrumentation layout



NOTE:
HATCHED AREAS ▨ ARE NOT PART OF TEST AREA.

Fig. E6 – Hold level instrumentation layout

Appendix F

Damaged Sensors for Wartime Demonstrations arm3w05 – arm3w08

Damaged Sensors

arm3w05

Compartment	Channels	Damage Type
Crew Living	50a, 51a, 52a, 53a	-5000
Comm Center	55a, 56a, 57a, 58a	-5000
Combat Systems	15a, 16a	+/- 50 * Actual
AMR 1 – 4^{th} Deck	104a, 105a, 106a, 107a	-5000
AMR 1 – 5^{th} Deck	110a, 111a, 112a, 113a	-5000
CIC Vestibule	120b, 121b	-5000
Radio Transmitter Room	135b, 136b	-5000
Combat Systems	94b, 95b	+/- 50%
CPO Living	167b, 168b	+/- 50%
CIC	169b, 170b	-5000

arm3w06

Compartment	Channels	Damage Type
Crew Living	50a, 51a, 52a, 53a	-5000
Comm Center	55a, 56a, 57a, 58a	-5000
AMR 1 – 4^{th} Deck	104a, 105a, 106a, 107a	-5000
AMR 1 – 5^{th} Deck	110a, 111a, 112a, 113a	-5000
Engineering Storeroom	85a, 86a	+/- 50%
Engineering Storeroom	97a, 98a	+/- 50%
Tomahawk Equipment Room Vestibule	102a, 103a	+/- 50 * Actual
Engineering Storeroom	130a, 131a	+/- 50 * Actual
CIC Vestibule	120b, 121b	-5000
Radio Transmitter Room	135b, 136b	-5000
CIC	169b,170b	-5000
Tomahawk	141b, 143b	+/- 50 * Actual
Engineering Storeroom	147b, 148b	+/- 50 * Actual

arm3w07

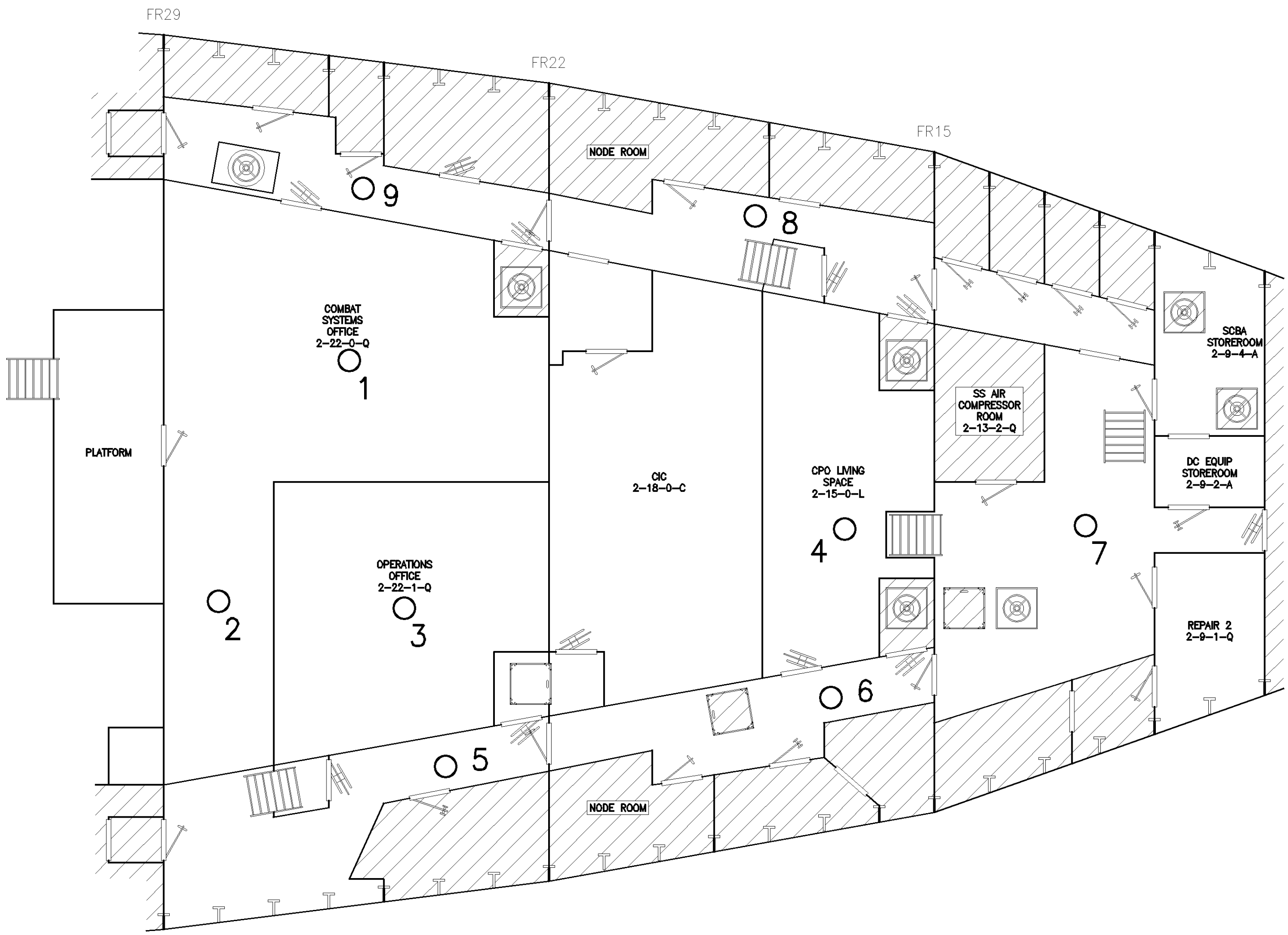
Compartment	Channels	Damage Type
Crew Living	50a, 51a, 52a, 53a	-5000
Comm Center	55a, 56a, 57a, 58a	-5000
AMR 1 – 4^{th} Deck	104a, 105a, 106a, 107a	-5000
AMR 1 – 5^{th} Deck	110a, 111a, 112a, 113a	-5000
Engineering Storeroom	85a, 86a	+/- 50%
Engineering Storeroom	97a, 98a	+/- 50%
Tomahawk Equipment Room Vestibule	102a, 103a	+/- 50 * Actual
Engineering Storeroom	130a, 131a	+/- 50 * Actual
CIC Vestibule	120b, 121b	-5000
Radio Transmitter Room	135b, 136b	-5000
CIC	169b,170b	-5000
Tomahawk	141b, 143b	+/- 50%
Engineering Storeroom	147b, 148b	+/- 50%

arm3w08

Compartment	Channels	Damage Type
Crew Living	50a, 51a, 52a, 53a	-5000
Comm Center	55a, 56a, 57a, 58a	-5000
AMR 1 – 4^{th} Deck	104a, 105a, 106a, 107a	-5000
AMR 1 – 5^{th} Deck	110a, 111a, 112a, 113a	-5000
Combat Systems	15a, 16a	+/- 50 * Actual
	73a, 74a	+/- 50 * Actual
CIC Vestibule	120b, 121b	-5000
Radio Transmitter Room	135b, 136b	-5000
CIC	169b,170b	-5000
Combat Systems	94b, 95b	+/- 50 * Actual
CPO Living	167b, 168b	+/- 50 * Actual

Appendix G

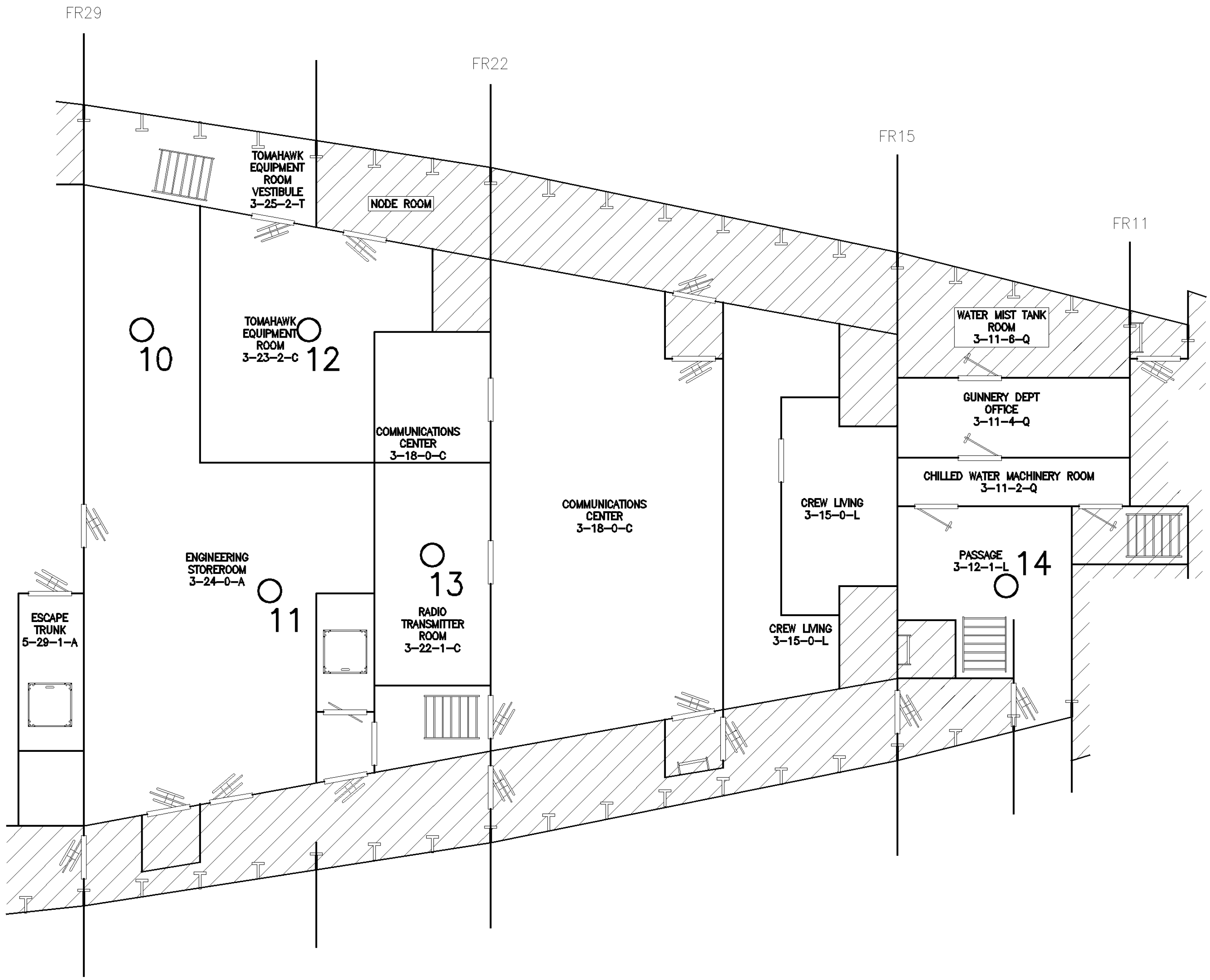
EWFD Detector Locations



NOTE:
HATCHED AREAS ▨ ARE NOT PART OF TEST AREA.

○ EWFD LOCATION

Fig. G1 – Second deck EWFD layout



NOTE:
HATCHED AREAS ▨ ARE NOT PART OF TEST AREA.

○ EWFD LOCATION

Fig. G2 – Third deck EWFD layout

Appendix H

COTS Detector Locations

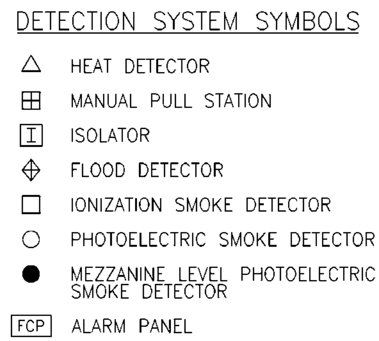


Fig. H1 – COTS symbols key

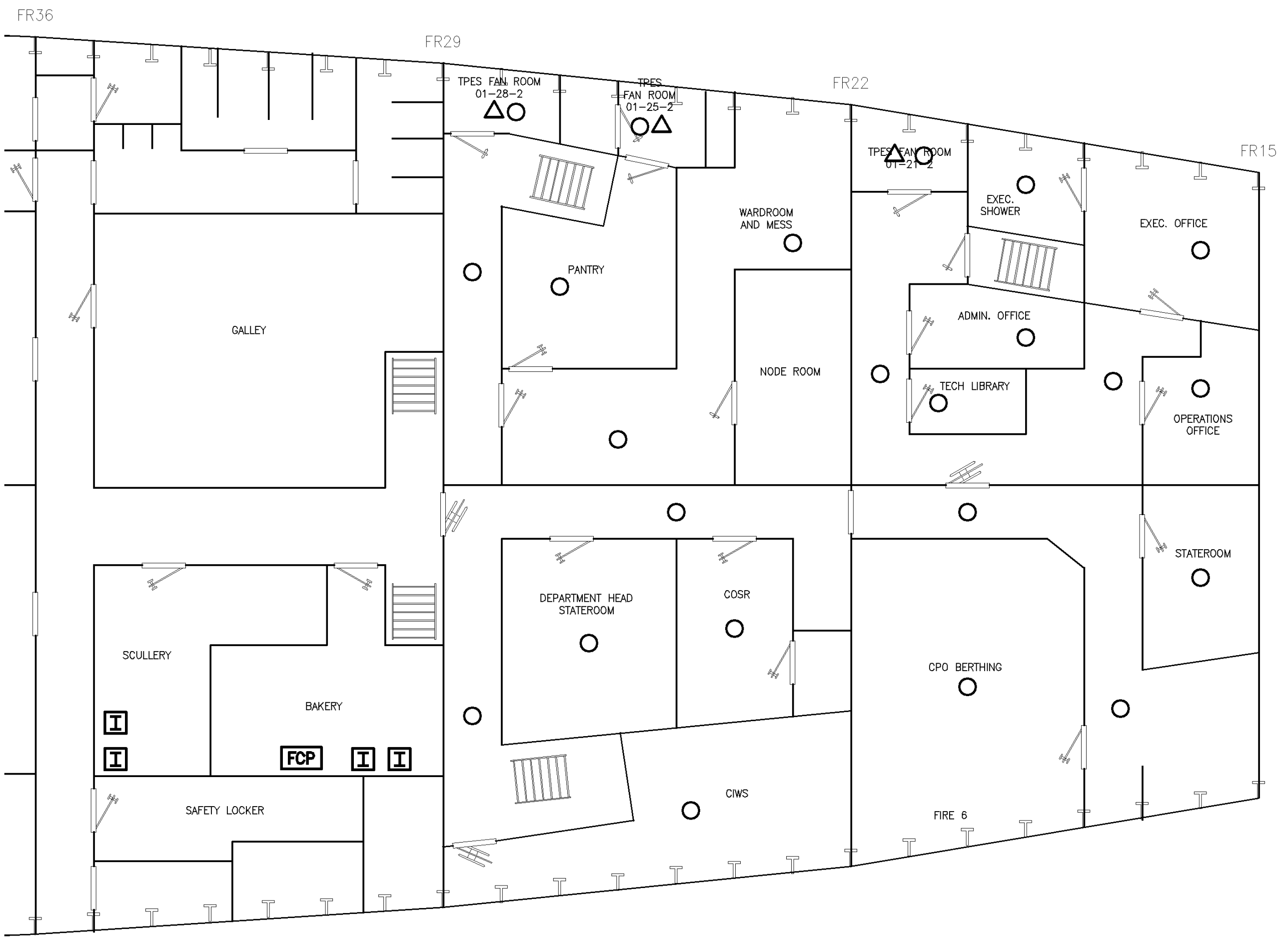


Fig. H2 – 01 level COTS detector layout

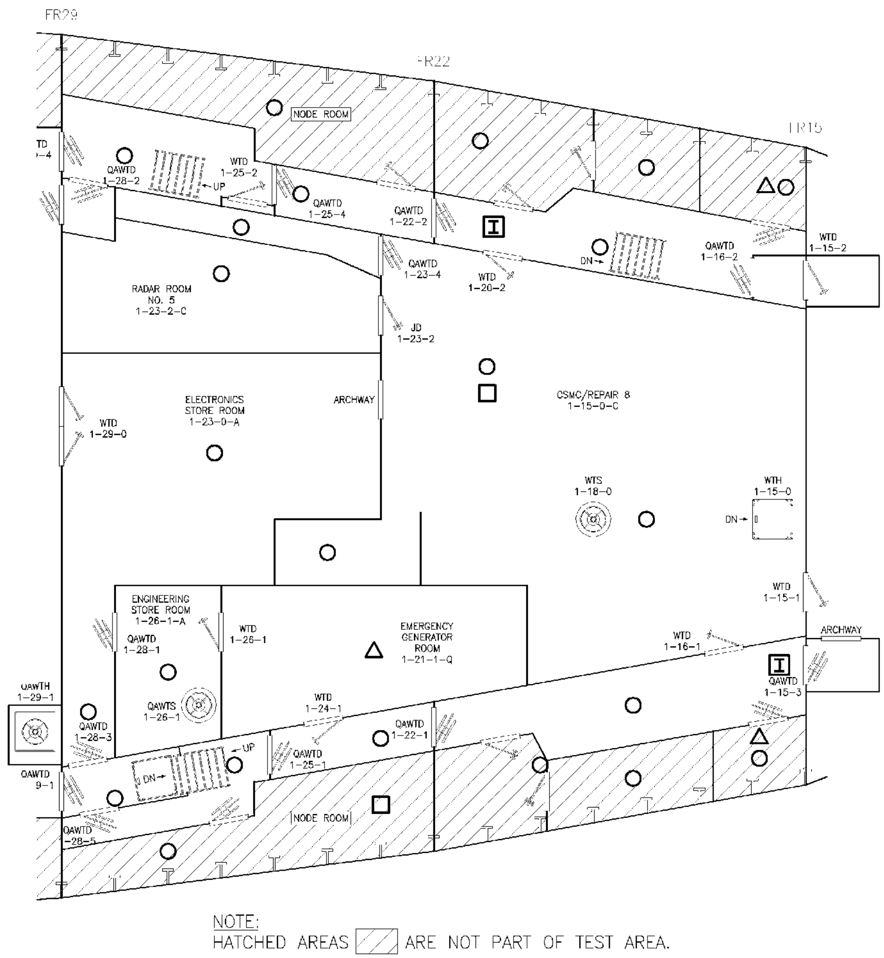
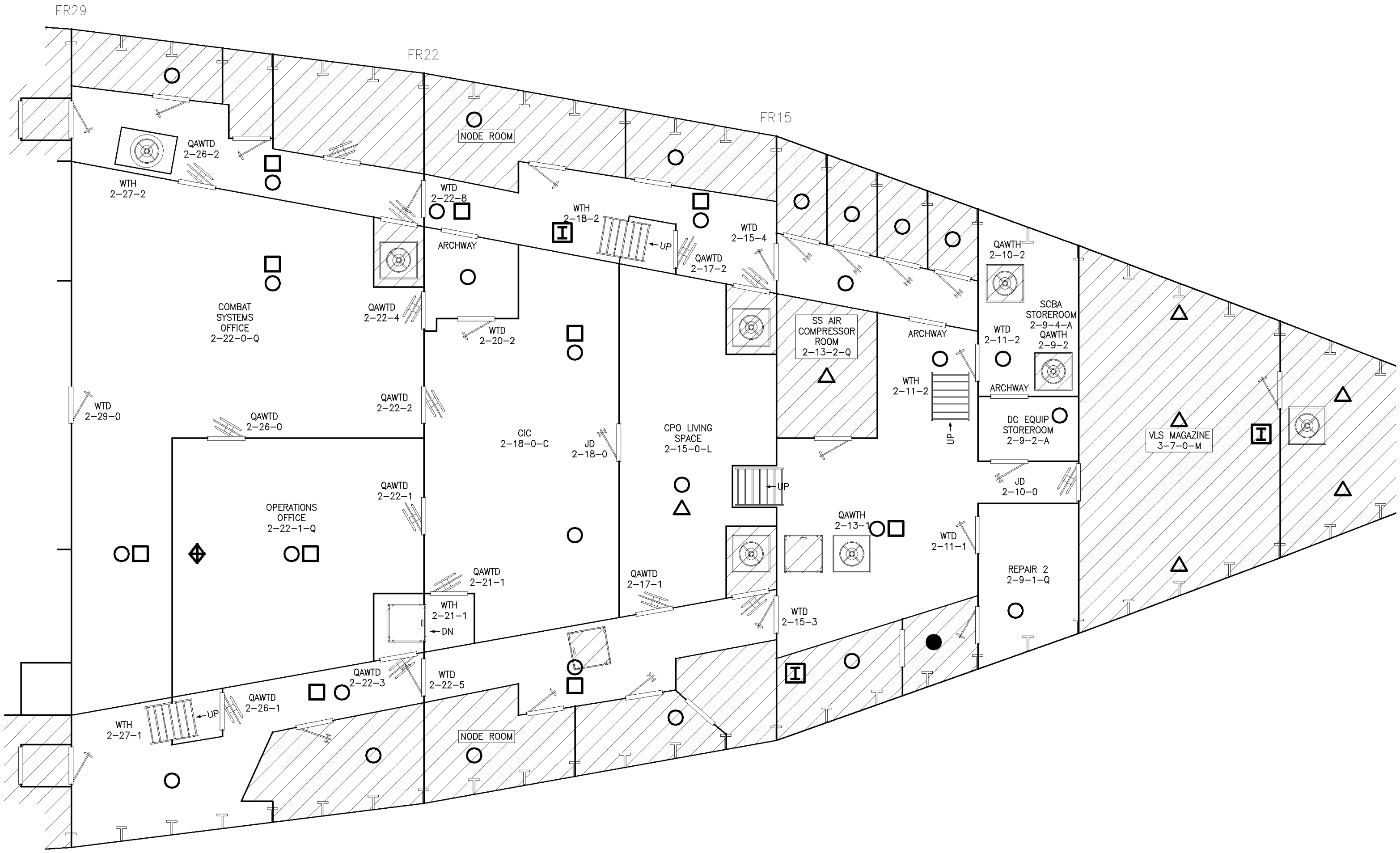


Fig. H3 – Main deck COTS detector layout



NOTE:
HATCHED AREAS ARE NOT PART OF TEST AREA.

Fig. H4 – Second deck COTS detector layout

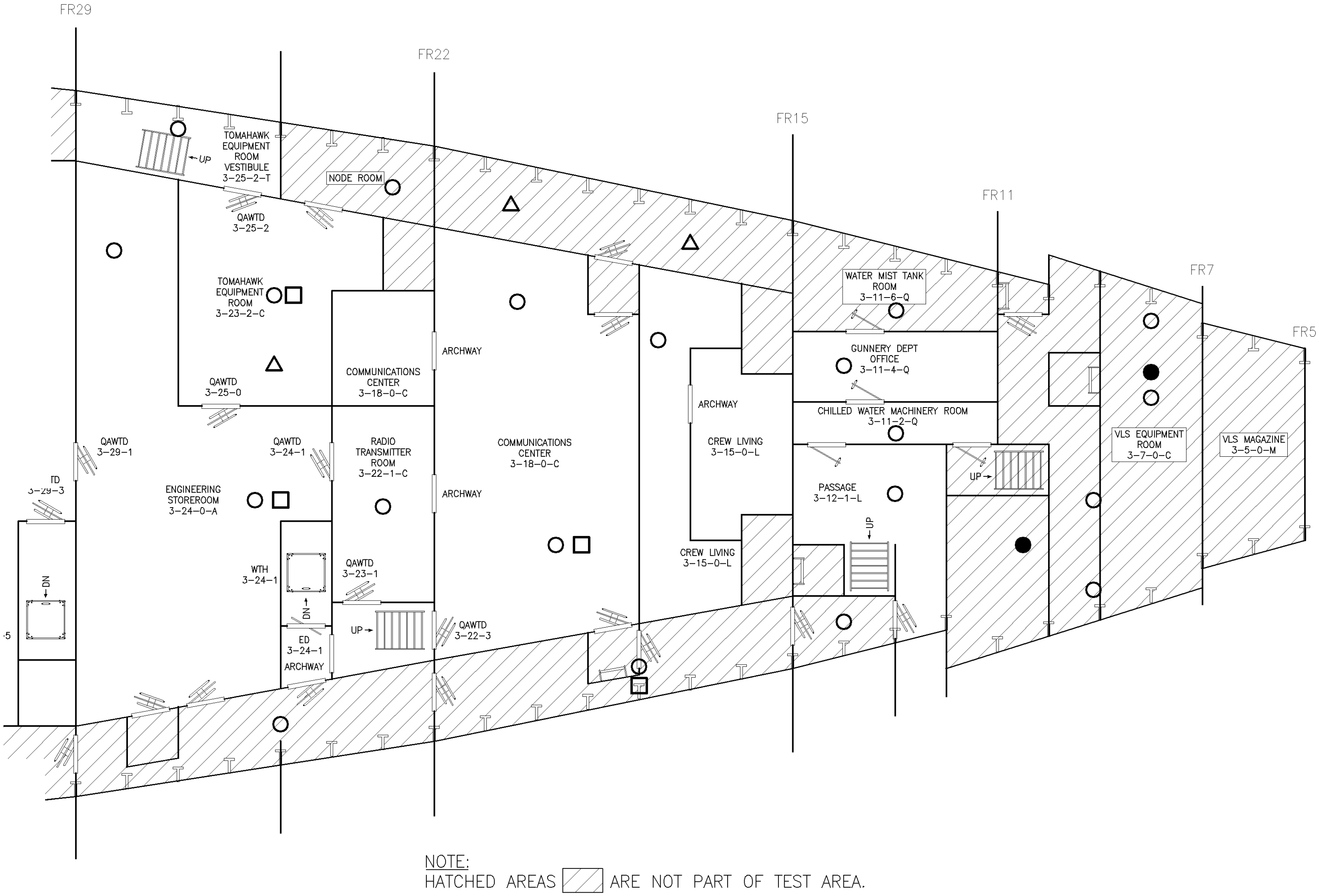


Fig. H5 – Third deck COTS detector layout

Appendix I

Video Camera Locations

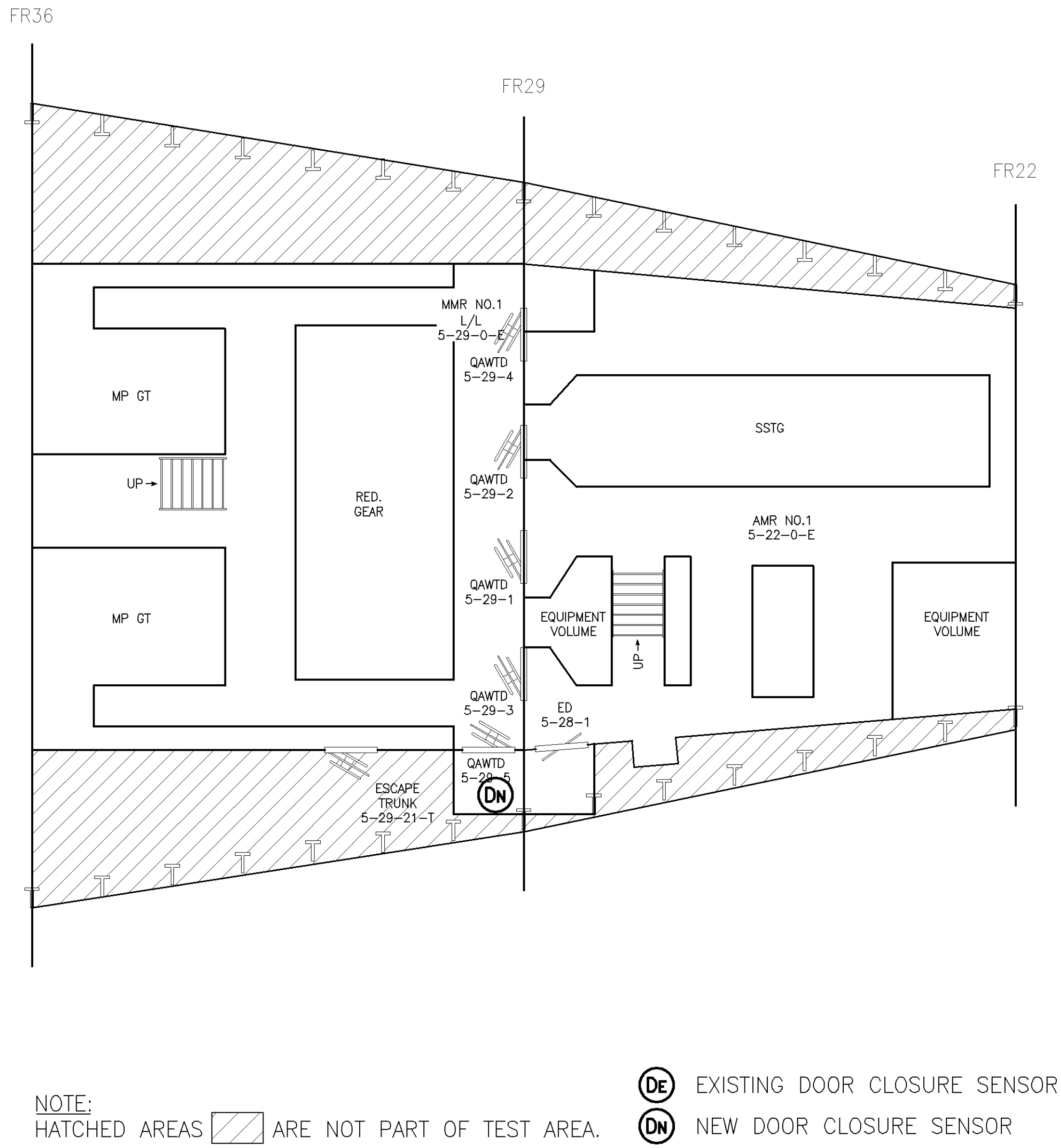


Fig. J5 – Hold level door closure sensor layout

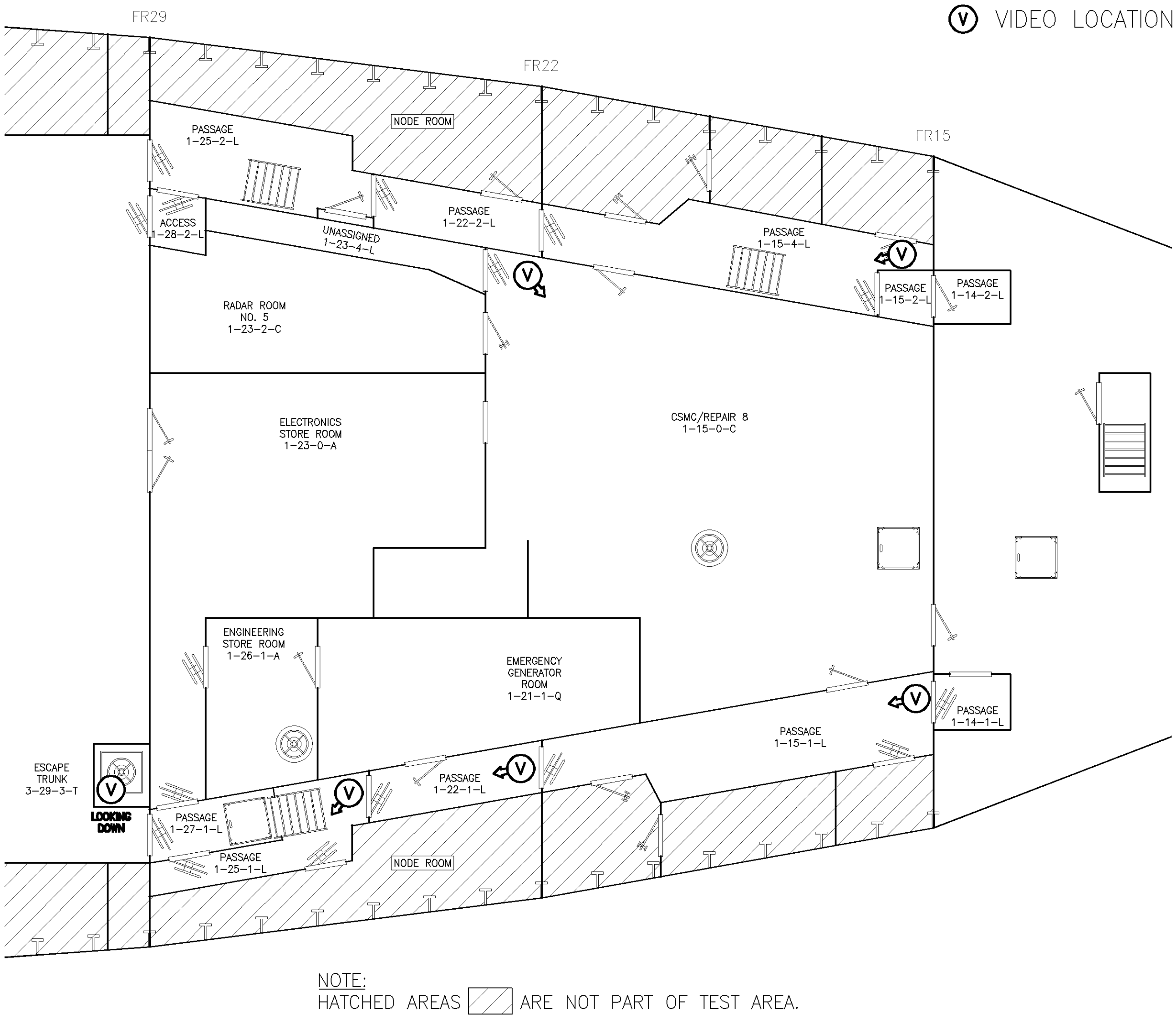


Fig. I1 – Main deck video camera layout

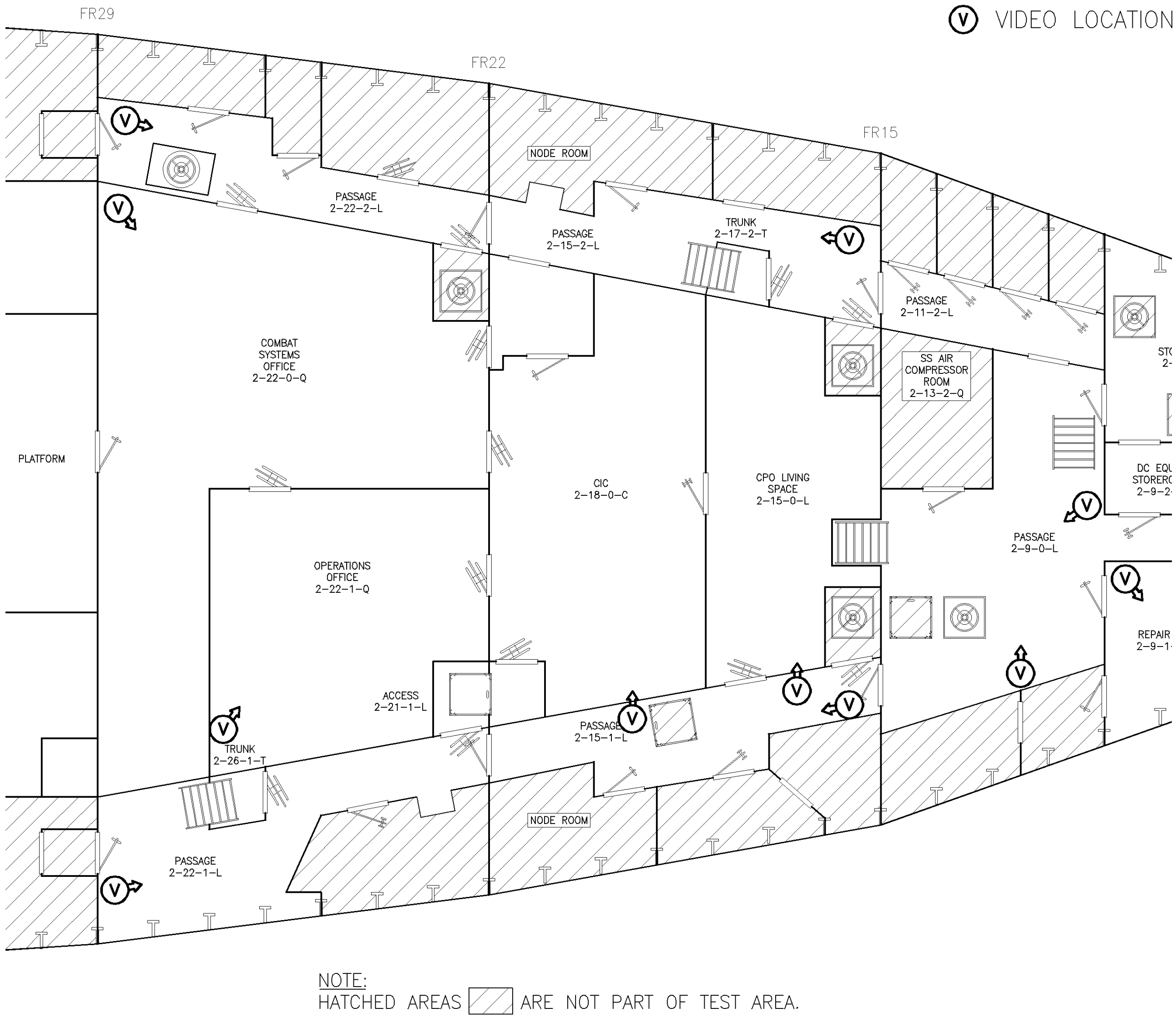


Fig. I2 – Second deck video camera layout

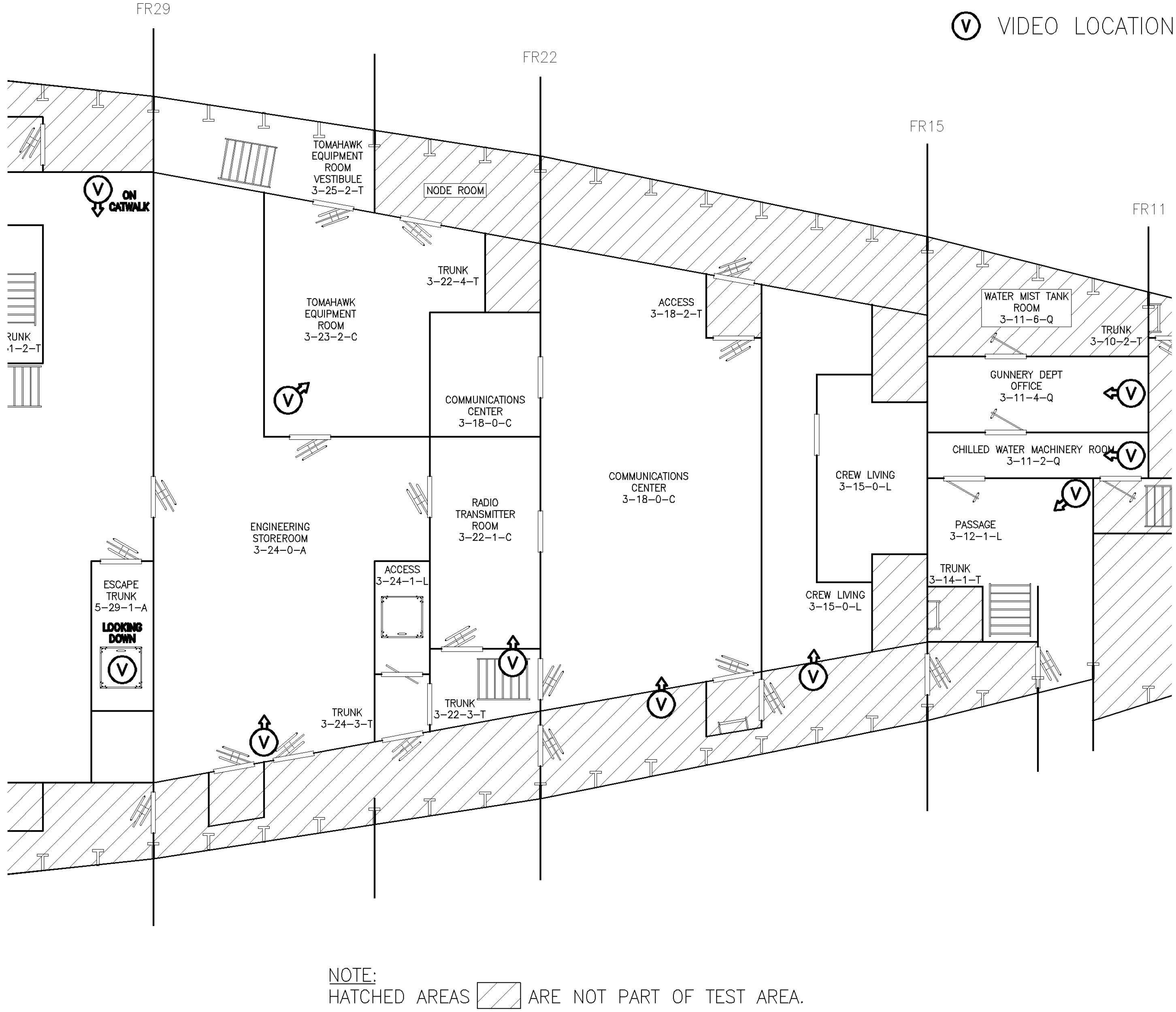


Fig. I3 – Third deck video camera layout

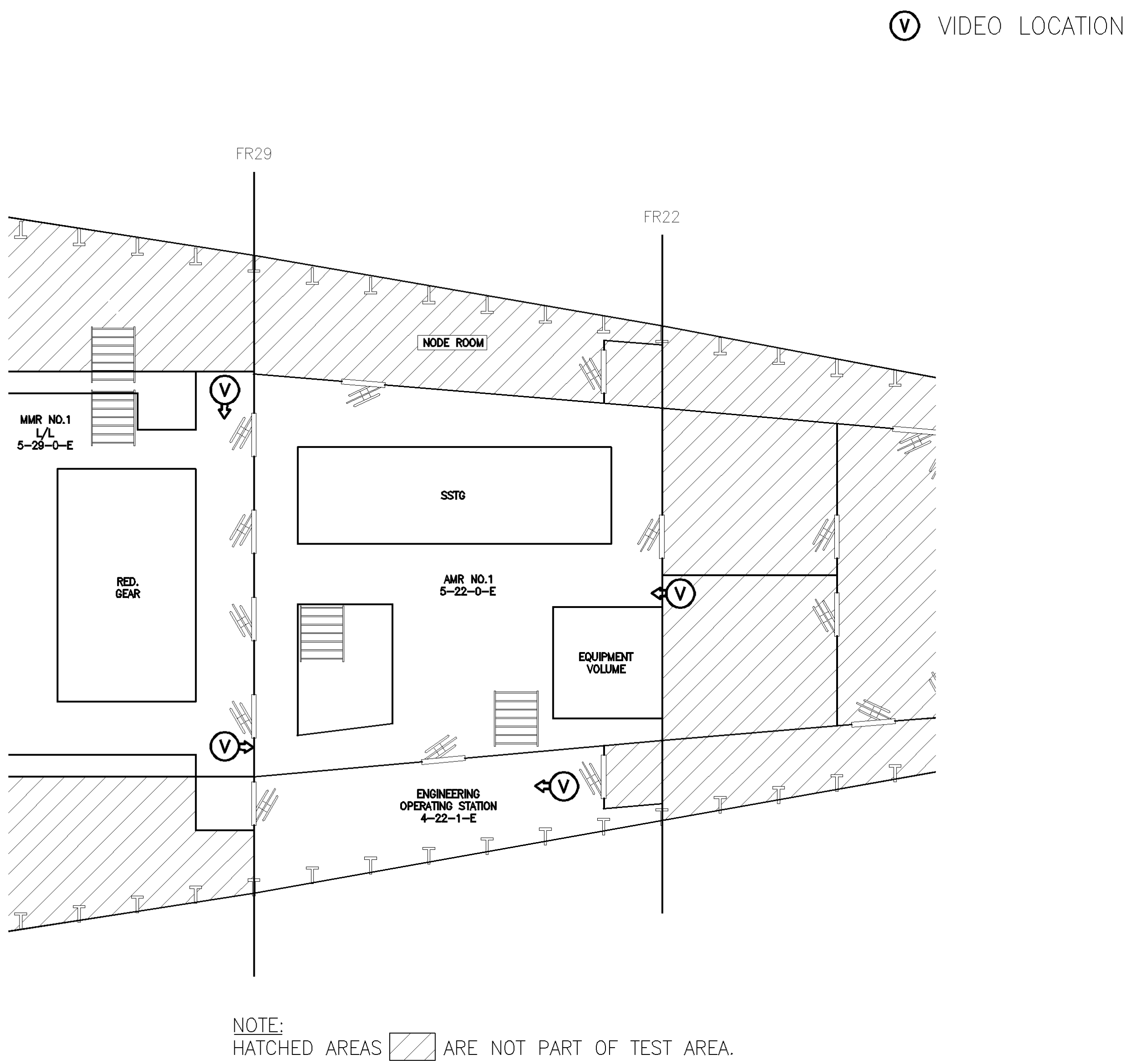


Fig. I4 – Fourth deck video camera layout

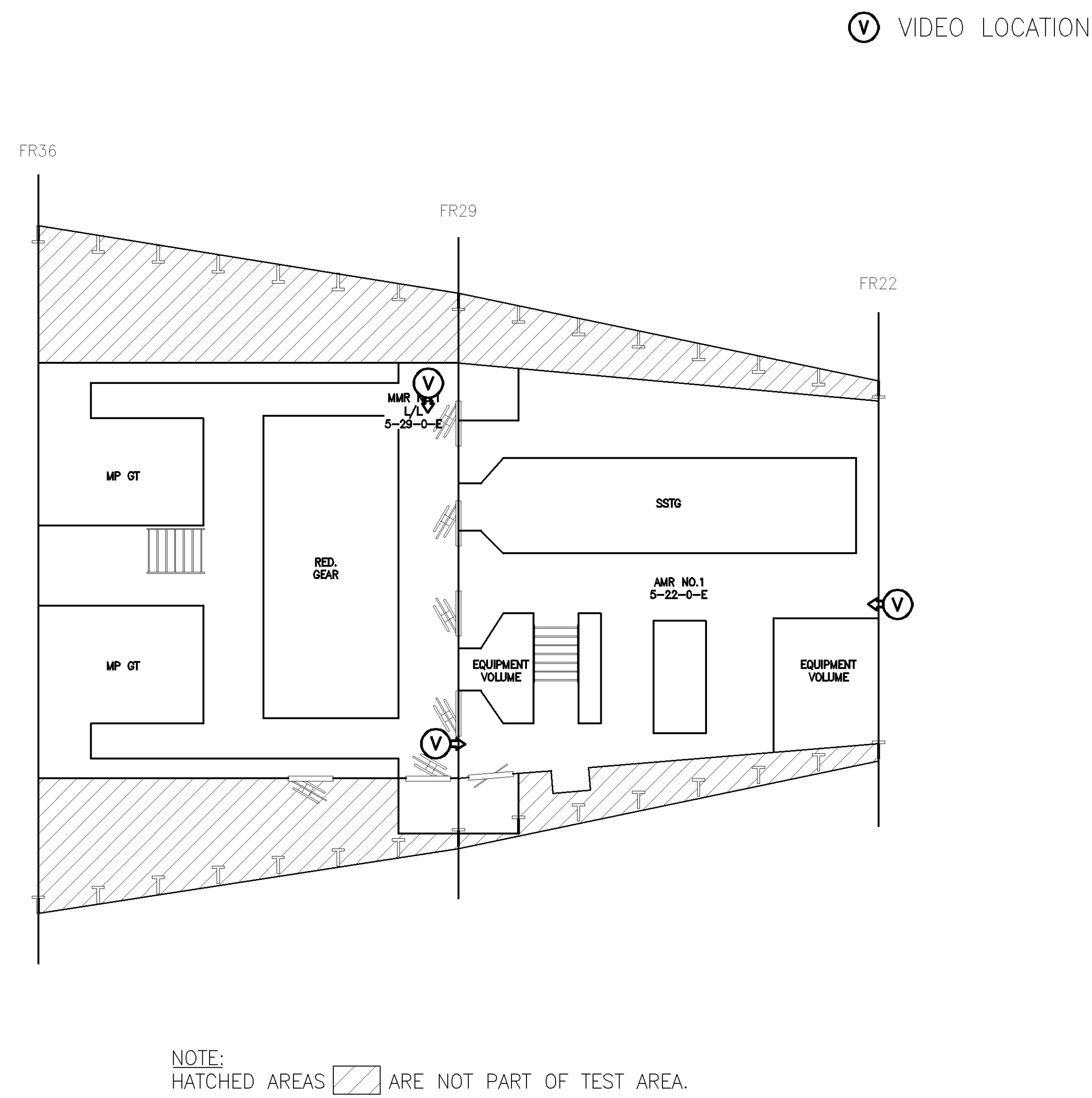


Fig. I5 – Hold level video camera layout

Appendix J

Door Closure Sensor Locations

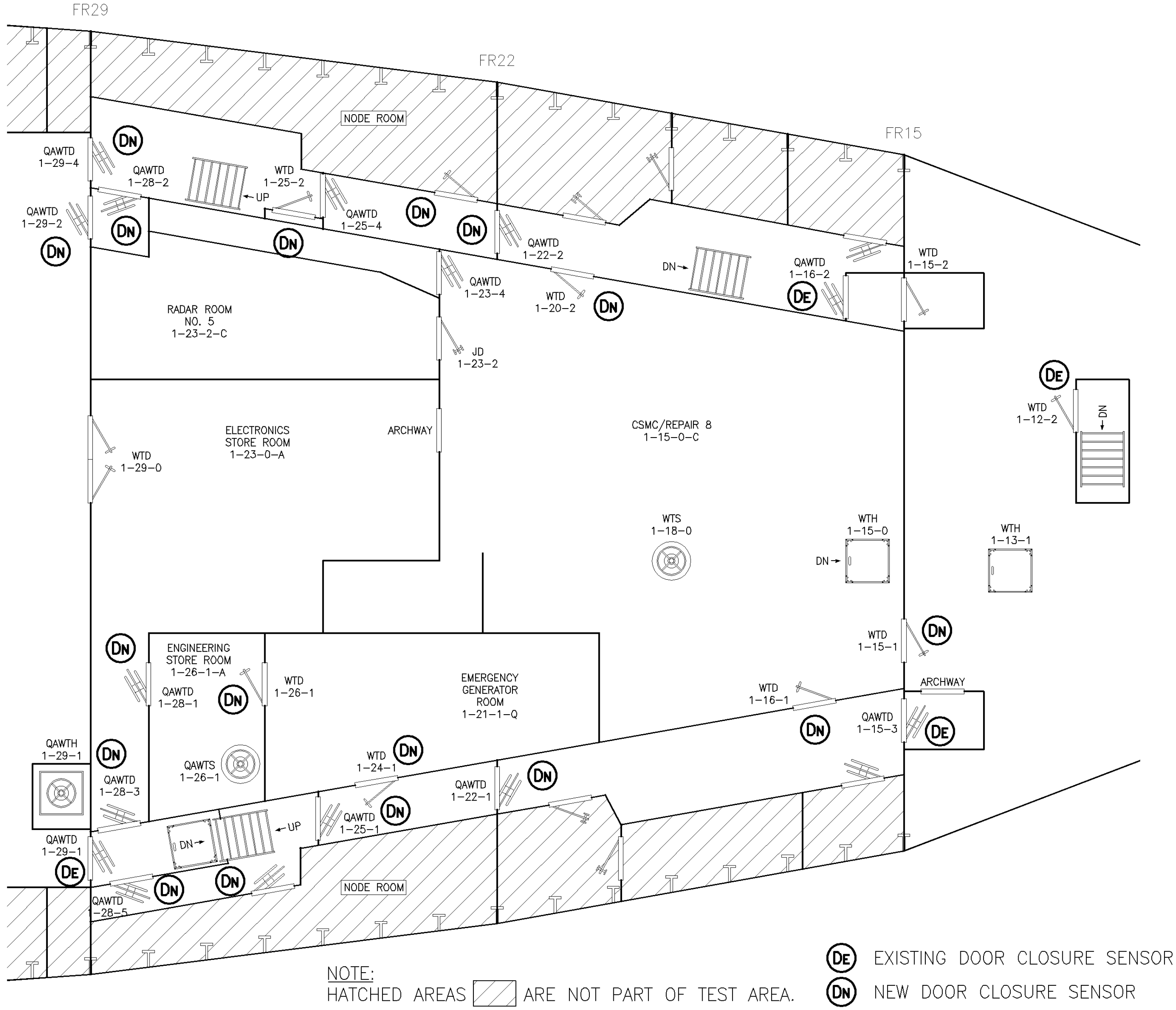


Fig. J1 – Main deck door closure sensor layout

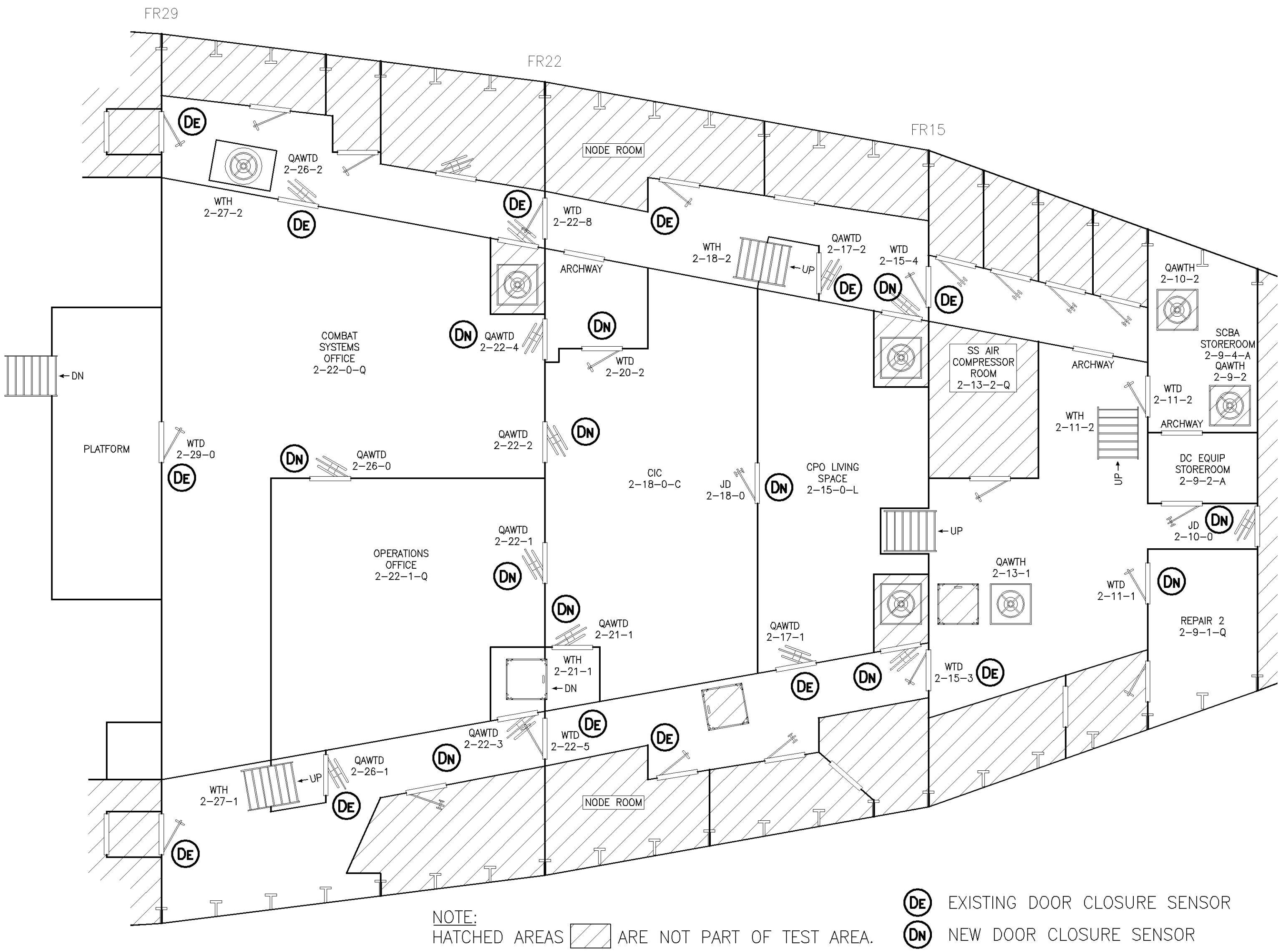


Fig. J2 – Second deck door closure sensor layout

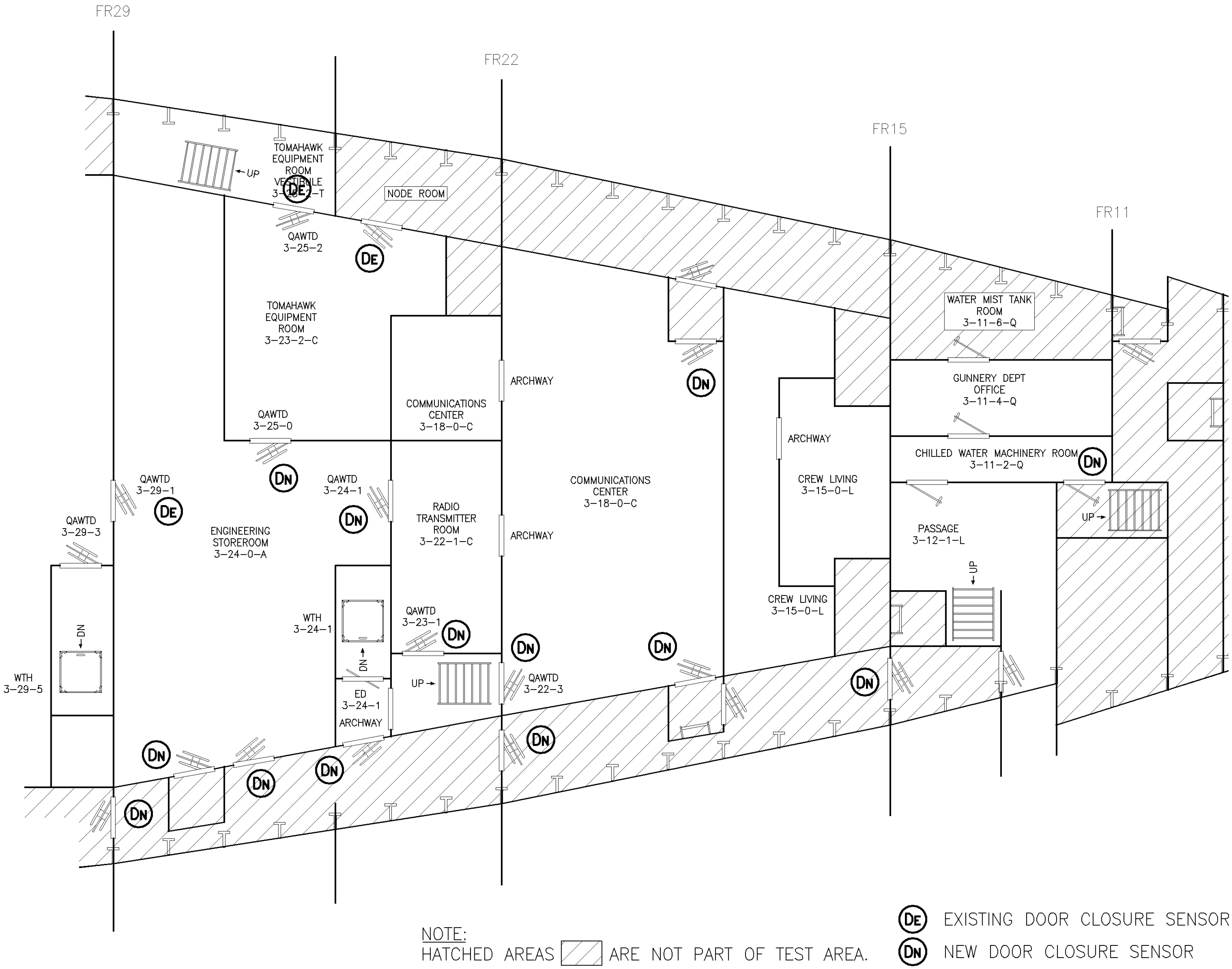
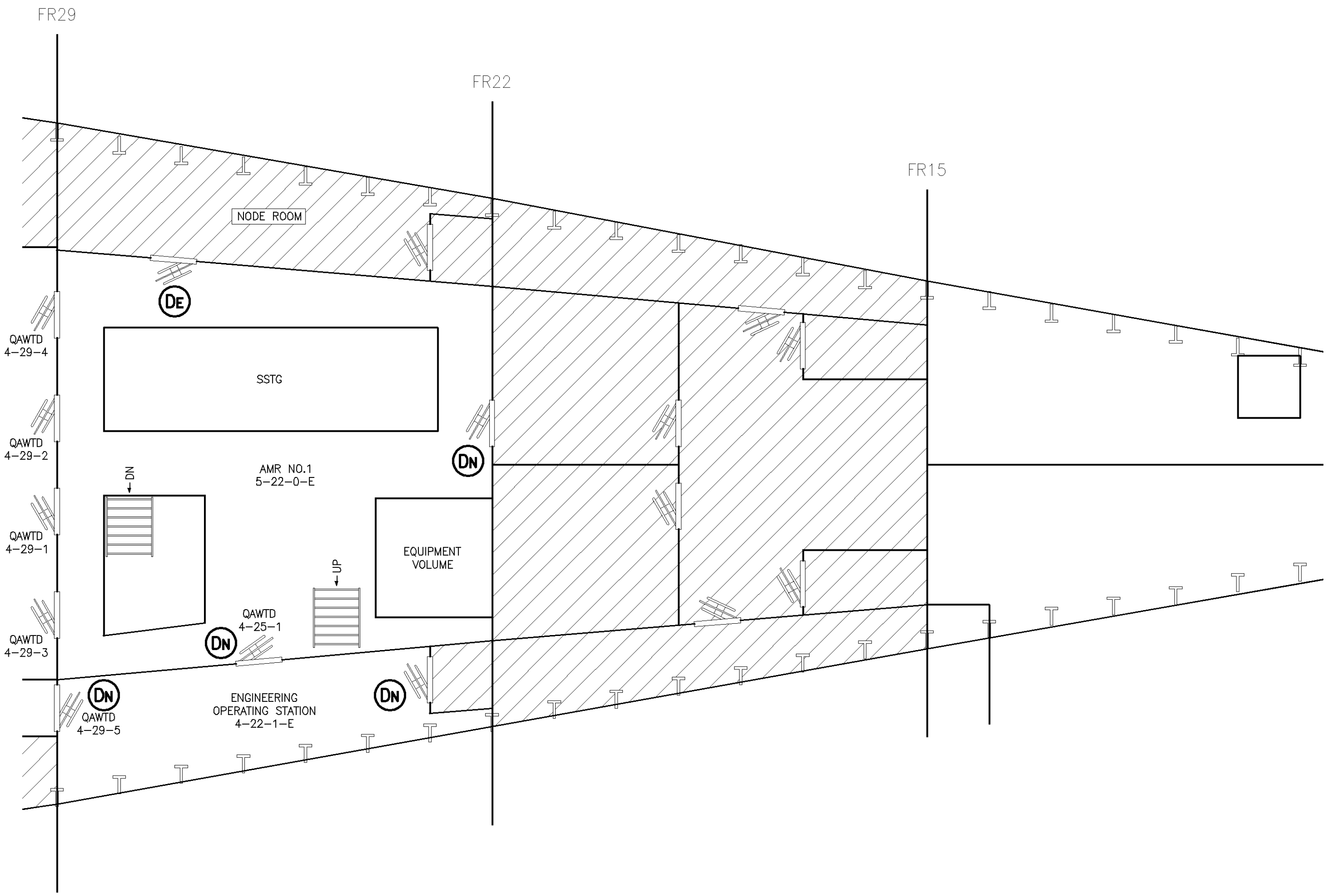


Fig. J3 – Third deck door closure sensor layout



NOTE:
HATCHED AREAS ARE NOT PART OF TEST AREA.

DE EXISTING DOOR CLOSURE SENSOR
DN NEW DOOR CLOSURE SENSOR

Fig. J4 – Fourth deck door closure sensor layout

Appendix K

Timelines for Peacetime Demonstrations arm3p01 – arm3p04, arm3p06

Demonstration: arm3p01 Date: September 10, 2001

Description: Trash can with bathroom trash in Passage 3-12-0

Actual Time	Elapsed Time	Event
13:59:52	0:00	The Safety Team initiated the trash can fire in Passage 3-12-0.
14:01:06	1:14	The Passage 3-12-0 EWFD issued warning.
14:01:16	1:24	The Passage 3-12-0 EWFD alarmed.
14:01:56	2:04	The Passage 3-13-3-L COTS (ion) detector alarmed.
14:02:22	2:30	The SCS received notification that a fire was detected by the EWFD system. Based on this report, SCS classified the fire as a small fire.
14:02:24	2:32	A fire in Passage 3-12-1-L was called away by the DC Watch Supervisor over the 1MC.
14:02:25	2:33	The SCS requested video of compartment 3-12-1-L, Passage.
14:03:19	3:27	The Primary Responders arrived on the 3rd deck, Passage 3-12-0.
14:03:58	4:06	The Primary Responders extinguished the fire using a portable H_20 extinguisher.
14:05:13	5:21	The On-Scene Leader reported to DC Central that the fire had been extinguished.
14:06:12	6:20	Personnel in the Control Room ventilated the test space by activating fan E1-15-1.
14:06:52	7:00	Demonstration completed.

Demonstration: arm3p02 Date: September 10, 2001

Description: Smoldering cable with calrod in Passage 2-9-0, on top of Repair 2 door. Toasting Pop-Tarts in CPO Living

Actual Time	Elapsed Time	Event
14:17:39	0:00	Heating element (calrod) in Passage 2-9-0 initiated by Safety Team personnel.
14:19:50	2:11	Safety Team began toasting pop-tarts in CPO Living. The Repair 2 EWFD alarmed.
14:20:13	2:34	SCS reported small fire in Passage 2-9-0, based on EWFD system data. Video of compartment appeared on screen in DC Central.
14:20:18	2:39	A fire in Passage 2-9-0 was called away by the DC Watch Supervisor over the 1MC.
14:20:32	2:53	The Primary Responders arrived on-scene outside of Repair 2.
14:20:39	3:00	The Passage 2-9-1 COTS (photo #1) detector alarmed.
14:20:51	3:12	The Passage 2-9-1 COTS (photo #2) detector alarmed. The Primary Responders began to extinguish the fire using a portable CO_2 extinguisher.
14:22:21	4:42	The remaining members of the Rapid Response Team (Attack Team and On-Scene Leader) arrived on-scene outside of Repair 2.
14:22:34	4:55	On-Scene Leader called DC Central to report that fire had been extinguished. Demonstration completed.

Demonstration: arm3p03 Date: September 11, 2001

Description: Computer Monitor in Operations Office
Diesel Engine in Passage 3-29-0

Actual Time	Elapsed Time	Event
12:50:30	0:00	Heating element (calrod) for computer monitor initiated by Safety Team personnel.
12:50:50	0:20	Diesel engine started by Safety Team.
12:51:58	1:28	Steady stream of smoke observed from the computer monitor.
12:54:12	3:42	The Operations Office EWFD (#3) issued warning.
12:54:14	3:44	SCS requested video of the Operations Office based on warning from EWFD.
12:54:16	3:46	The Operations Office EWFD (#3) alarmed.
12:54:24	3:54	SCS received alarm in the Operations Office from EWFD system. Small fire reported by SCS system.
12:54:28	3:58	SCS requested video of the Operations Office based on EWFD alarm.
12:54:30	4:00	DC Watch Supervisor announced fire in Operations Office over the 1 MC.
12:54:36	4:06	Video appeared on screen in DC Central.
12:54:40	4:10	SCS recommended dispatching the RRT to the Operations Office for a direct fire attack (Estimated travel time 1 min, 54 sec).
12:55:00	4:30	Rapid Response Team en-route to the Operations Office.
12:55:09	4:39	The Operations Office COTS (ion – 103I) detector alarmed.
12:55:21	4:51	The Operations Office COTS (photo – 053P) detector alarmed.
12:55:52	5:22	The Rapid Response Team on-scene in the Operations Office.
12:56:03	5:33	Flames observed from the computer monitor in the Operations Office.
12:56:18	5:48	The RRT began to extinguish in the fire in the Operations Office using

Demonstration: arm3p03 Date: September 11, 2001

Actual Time	Elapsed Time	Event
		H_20 extinguisher (CR & DC)
12:56:30	6:00	The RRT reported to DC Central that the fire in the Operations Office had been extinguished.
12:57:00	6:30	DCO acknowledged report of “fire out” and input report into SCS.
12:57:08	6:38	SCS updated screen in DC Central to reflect “fire out” in the Operations Office.
12:58:12	7:42	SCS acknowledged DC Watch Supervisor input that the fire had been extinguished.
13:18:08	27:38	Safety Team opened the doors to the Radio Transmitter Room and stbd passage on the 3rd deck.
13:23:00	32:30	Diesel engine secured by Safety Team.
13:24:00	33:30	Control Room personnel ventilated the test space by activating fans E-15-1 and E-15-2. Demonstration completed.

Demonstration: arm3p04 Date: September 11, 2001

Description: Tomahawk Equipment Room – Smoldering electrical cable (by the node room, variac set at 50 V)
CPO Living – Grinding steel (Nuisance)

Actual Time	**Elapsed Time**	**Event**
13:54:50	0:00	Safety Team personnel initiated the heating element (calrod) in the Tomahawk Equipment Room.
13:54:57	0:07	Safety Team personnel began grinding the painted bulkhead in CPO Living.
13:55:49	0:59	Single probability value above 0.85 on EWFD#4 – CPO Living
13:55:50	1:00	CPO Living EWFD alarmed. SCS received alarm in CPO Living from EWFD system. Small fire reported by SCS system.
13:55:56	1:06	SCS requested video of CPO Living based on EWFD alarm.
13:56:04	1:14	CPO Living COTS (photo – 004P) detector alarmed.
13:56:05	1:15	Video of CPO Living appeared on screen in DC Central.
13:56:08	1:18	SCS recommended dispatching RRT to CPO Living for direct attack. (Estimated travel time 1 min, 32 sec)
13:56:56	2:06	CPO Living COTS (ion – 101I) detector alarmed.
13:57:21	2:31	CPO Living COTS (ion – 101I) detector alarmed.
13:58:01	3:11	CPO Living COTS (photo – 004P) detector alarmed.
13:58:40	3:50	Safety Team personnel secured grinding in CPO Living. Safety Team increased variac to 60 V.
13:59:10	4:20	Control Room personnel activated fan E-1-15-1.
14:00:25	5:35	SCS restarted for next test.
14:22:22	27:32	Tomahawk Equipment Room COTS (photo – 001P) alarmed.

Demonstration: arm3p04 Date: September 11, 2001

Actual Time	Elapsed Time	Event
14:24:04	29:14	Tomahawk Equipment Room EWFD issued warning.
14:26:40	31:50	Tomahawk Equipment Room COTS (photo – 001P) alarmed
14:31:56	37:06	Tomahawk Equipment Room EWFD alarmed.
14:32:02	37:12	SCS received alarm in Tomahawk Equipment Room from EWFD system. Small fire reported by SCS system
14:32:08	37:18	SCS requested video of Tomahawk Equipment Room based on alarm from EWFD system.
14:32:09	37:19	SCS recommended dispatching the RRT to Tomahawk Equipment Room for a direct fire attack (Estimated travel time 3 min, 48 sec).
14:32:28	37:38	DC Watch Supervisor called away a fire in the Tomahawk Equipment Room over the 1 MC.
14:32:50	38:00	RRT en-route to Tomahawk Equipment Room.
14:34:00	39:10	RRT on-scene in Tomahawk Equipment Room, secured power for calrod, report no fire.
14:35:49	40:59	Tomahawk Equipment Room COTS (photo – 001P) alarmed.
14:35:52	41:02	Personnel in the Control Room began to ventilate the space. Demonstration completed.

Demonstration: arm3p06 Date: September 12, 2001

Description: Operations Office – Smoldering mattress and bedding (Calrod at 50 V)
Engineering Storeroom – Welding (Nuisance)

Actual Time	Elapsed Time	Event
13:45:47	0:00	Safety Team personnel initiated heating element (calrod) in the Operations Office.
13:46:42	0:55	Safety Team members started welding in the Engineering Storeroom.
13:47:30	1:43	Stbd EWFD in Engineering Storeroom reached probability value of 0.60.
13:47:37	1:50	SCS received EWFD warning (based on detector at 60%).
13:47:43	1:56	SCS requested video of Engineering Storeroom based on warning from EWFD system.
13:47:46	1:59	Engineering Storeroom COTS (photo – 095P) detector alarmed.
13:48:00	2:13	Engineering Storeroom EWFD issued a warning and an alarm.
13:48:01	2:14	SCS received alarm in Engineering Storeroom from EWFD system. Small fire reported by SCS system.
13:48:05	2:18	Video started in Engineering Storeroom.
13:48:12	2:25	DCC announced fire in Engineering Storeroom and called away the Rapid Response Team.
13:48:13	2:26	SCS recommended dispatching the RRT to Engineering Storeroom for Direct Fire Attack (Estimated time of travel - 3 min, 48 sec).
13:49:30	3:43	The RRT arrived on-scene in the Engineering Storeroom and reported “no fire”.
13:49:58	4:11	Report made to SCS that the fire was called out by RRT. Video of the Engineering Storeroom was closed.
13:50:00	4:13	SCS reported fire cleared in Engineering Storeroom
13:51:20	5:33	The Engineering Storeroom COTS (ion – 094I) detector alarmed.

Demonstration: arm3p06 Date: September 12, 2001

Actual Time	Elapsed Time	Event
13:55:14	9:27	SCS received alarm in the Operations Office from EWFD system (based on single probability value at or above 0.85). Small fire reported by SCS system.
13:56:44	10:57	DCC reported a fire in the Operations Office and called away the Rapid Response Team
13:57:30	11:43	The RRT on-scene in the Operations Office
13:57:42	11:55	The Operations Office EWFD reached 60%
13:57:48	12:01	The Operations Office EWFD issued warning
13:57:52	12:05	The Operations Office EWFD issued alarm (based on three consecutive probability values of 0.85).
13:58:15	12:28	The RRT reported that the fire in the Operations Office had been extinguished
13:58:40	12:53	Control Room personnel activated fans E1-15-1 and E1-15-2. Demonstration completed.

Appendix L

Timelines for Work up and Wartime Demonstrations arm3w02, arm3w05 – arm3w08

Test Description:
Peacetime Main Space Fire Locations -

- CIC – Wood-crib

Firemain Rupture Location

- Ops Office and Second Deck, Starboard Passage

Actual Time	Elapsed Time	Event
12:46:21	0:00	Safety Team members ignited wood crib in CIC.
12:48:40	2:19	SCS detected a medium fire in compartment 2-18-0-C, CIC based on elevated temperatures in the space.
12:48:47	2:26	SCS requested video of CIC based on the detected fire in this compartment. No video of this compartment was available.
12:49:04	2:43	SCS recommended dispatching the Rapid Response Team to CIC for a direct fire attack.
12:49:16	2:55	DC Watch Supervisor called away a fire in CIC over the 1 MC.
12:50:24	4:03	RRT on-scene in CIC, confirmed Class A fire in space. RRT also reported that the water mist system in this compartment did not appear to be operable. *(Under normal conditions, the RRT would have extinguished this fire. For test reasons, it was allowed to continue to burn).*
12:52:31	6:10	SCS detected a medium fire in CPO Living, based on elevated temperatures in the space.
12:52:45	6:24	SCS requested video of CPO Living based on the detected fire in this compartment. Video popped-up on screen, no fire observed on video.
12:52:44	6:23	SCS energized water mist in CPO Living in Fire Suppression mode, based on the medium fire detected in the space..
12:53:03	6:42	SCS reclassified the fire in CPO Living as a small fire.
12:53:08	6:47	SCS secured water mist in CPO Living from FS mode.
12:53:23	7:02	SCS reclassified the fire in CPO Living as a medium fire.
12:53:46	7:25	Fire cleared in CPO Living based on observations made using video.
12:56:16	10:13	SCS automatically set fire boundaries around CIC, by activating water mist in BC mode, in Ops Office, Combat Systems, and CSMC/Repair 8. At this time temperatures water mist was not energized.

Actual Time	Elapsed Time	Event
12:56:17	10:14	SCS reported that fire boundaries were incomplete.
12:56:38	10:35	SCS recommended dispatching Attack Team #4 to maintain fire boundaries in Passage 2-15-2-L.
12:57:24	11:03	SCS activated the water mist system in BC mode in CPO Living.
12:57:43	11:22	SCS energized water mist in BC mode in CPO Living.
12:57:59	11:38	Safety team members closed the door to the Ops Office.
13:02:56	16:35	SCS recommended dispatching Investigator Team #1 to maintain fire boundaries in Passage 2-15-3-L.
13:05:42	19:21	SCS detected a medium fire in CPO Living.
13:06:13	20:32	Water mist energized in FS mode in CPO Living
13:08:09	22:28	RRT confirmed that there was no fire in CPO Living. Additionally personnel requested that water mist be secured in this compartment.
13:08:16	22:05	Fire cleared in CPO Living by DC Central personnel
13:08:35	22:24	Water mist secured from FS mode in CPO Living, switched to BC mode in this compartment.
13:09:24	23:03	Water mist energized in BC mode in CPO Living, system pulsed on and off at set intervals.
13:09:59	23:38	RRT confirmed that the fire in CIC was still burning
13:12:46	26:25	SCS detected medium fire in CPO Living.
13:12:58	26:37	SCS reclassified the fire in CPO Living as a large fire
13:14:26	28:05	DCC requested that RRT check CPO Living for possible fire.
13:15:18	28:57	SCS energized water mist in CSMC/Repair 8 in BC mode.
13:15:29	29:08	SCS re-energized water mist in FS mode in CPO Living

Actual Time	Elapsed Time	Event
13:17:00	30:39	Fire cleared in CPO Living.
13:17:19	30:58	SCS detected hostile platform within strike range.
13:17:21	31:00	SCS detected a medium fire in CPO Living
13:17:26	31:05	Captain announced “Warning Red” over the 1 MC
13:17:52	31:31	SCS reported that attack likely. Ordered zebra and general quarters set.
13:17:56	31:35	Captain announced “General Quarters” over the 1 MC.
13:18:13	31:52	SCS secured water mist in CSMC/Repair 8.
13:20:33	34:12	Missile hit
13:20:41	34:20	Control Room personnel initiated damage to selected data.
13:20:51	34:30	Control Room personnel activated fans E-1-15-1 & E-1-15-2.
13:20:56	34:35	SCS reclassified the fire in CIC as a fully-involved fire.
13:21:08	34:57	Control Room personnel initiated ruptures in Ops Office and 2nd Deck starboard passageway. SCS detected a fully-involved fire in 3-25-2-T, Tomahawk Access Trunk, based on bad sensor data in this compartment.
13:21:20	34:59	SCS recommended dispatching Attack Team #3 to CSMC/Repair 8 for an indirect fire attack of CPO Living.
13:21:21	35:00	SCS detected potential fire main ruptures.
13:22:16	36:35	SCS recommended dispatching Support Team #1 to maintain fire boundaries in Passage 2-22-2-L and Passage 2-15-2-L.
13:23:08	37:27	SCS automatically isolated the fire main ruptures.
13:24:04	37:43	SCS detected smoke in 1-15-4-L.
13:24:16	37:55	DCC sent an Attack Team to Tomahawk Equipment Room Vestibule to investigate possible fire.
13:24:27	38:06	SCS requested video of compartment 1-15-4-L, based on report of smoke in this space.

Demonstration: arm3w02 **Date: September 19, 2001**

Actual Time	Elapsed Time	Event
13:24:28	38:07	SCS recommended activating SES.
13:25:30	39:09	The Attack Team reported that there was no fire in Tomahawk Equipment Room Vestibule.
12:25:58	39:37	SCS reported smoke cleared in Passage 1-15-4-L.
13:26:50	40:29	DCC personnel dispatched the investigation teams to investigate designated areas.
13:27:36	41:15	Fire cleared in compartment 3-25-2-T, Tomahawk Equipment Room Vestibule.
13:28:45	42:24	Manual boundaries reported set on port and starboard sides
13:29:50	43:29	DCC personnel dispatched an Attack Team to extinguish the fire in CIC
13:32:52	46:31	A report was made that the fire in CIC had been extinguished by the Attack Team with a fire extinguisher.

Demonstration: arm3w05 **Date: September 24, 2001**

Test Description:
Main Space Fire Locations -
- AMR No. 1 – F76 pool fire
- Communications Center – Main spray fire and wood-crib
- Radio Transmitter Room – Wood crib

Sympathetic Ignition Location
- Tomahawk Equipment Room – One bin
- Engineering Storeroom – One bin
- Combat Systems – One bin
- CPO Living – Bedding Materials

Firemain Rupture Location
- Ops Office

Actual Time	**Elapsed Time**	**Event**
13:13:34	0:00	Control Room personnel energized the spray fire in the Comm Center and initiated damage to the instrumentation.
13:13:34	0:00	SCS detected a Fully-Involved fire in the Comm Center, based on bad sensor data and the predicted damage area.
13:13:35	0:01	SCS detected a Fully-Involved fire in the Radio Transmitter Room, based on bad sensor data and the predicted damage area.
13:13:39	0:05	SCS detected a Fully-Involved fire in CIC, based on bad sensor data and the predicted damage area.
13:13:41	0:07	SCS detected a Fully-Involved fire in Crew Living, based on bad sensor data and the predicted damage area.
13:13:48	0:14	SCS activated water mist in BC mode in the APDA compartments – CSMC, Tomahawk, CPO Living, Engineering Storeroom, Combat Systems and Ops Office. Water mist **was not** energized at this time.
13:13:50	0:16	Safety Team personnel ignited the fuel pan for the wood crib in the Radio Transmitter Room.
13:14:12	0:38	SCS recommended dispatching the Support Team to set manual fire boundaries in the passageways on the 2nd deck.
13:14:35	1:01	DCO requested investigators to investigate assigned areas. Fires had been identified in the following locations – CIC, Comm Center, Crew Living and the Radio Transmitter Room.
13:14:43	1:09	Control Room personnel initiated rupture in Ops Office.
13:14:57	1:23	DCO requested that Repair 2 personnel set manual fire boundaries on port and starboard sides, 2nd deck, where water mist was unavailable.

Actual Time	Elapsed Time	Event
13:15:02	1:28	SCS detected potential fire main rupture between valves 2-23-1 and 1-26-2.
13:15:04	1:30	Safety Team personnel ignited F-76 pan fire in AMR No. 1.
13:15:13	1:39	SCS detected a Medium fire in CPO Living, based on elevated temperatures in the space. At this time water mist was energized approximately 30 seconds and de-energized for 1 minute, 30 seconds, based on BC mode operation.
13:16:14	2:40	SCS detected a Medium fire in AMR No. 1, based on elevated temperatures in the compartment.
13:16:21	2:47	SCS isolated Ops Office fire main rupture.
13:16:23	2:49	DCO aware of potential fire main rupture. Viewed fire main screen – observed that the smart valves were closed and the rupture had been isolated.
13:16:45	3:11	Control Room personnel secured LPES.
13:16:46	3:12	SCS recommended dispatching the Attack Team to CSMC/Repair 8 to perform an indirect attack of CIC. SCS also recommended dispatching RRT to CSMC/Repair 8 for indirect attack of CIC.
13:16:48	3:14	Repair 2 Comm Operator reported fire boundaries set port and starboard, forward of CIC.
13:17:14	3:40	SCS recommended dispatching the Attack Team to Comm Center for a direct attack.
13:17:33	3:59	Investigation Team #2 reported Repair 8 clear.
13:17:40	4:06	Control Room personnel secured fan E 1-15-1.
13:18:00	4:26	Investigation Team #1 sent by the DCO to investigate possible fire AMR No. 1.
13:18:14	4:40	DCO requested manual fire boundaries in Engineering Operations Station.
13:18:38	5:04	DC Watch Supervisor reported lost fire plugs to Casualty Coordinator, at the request of the DCO.
13:19:38	6:04	Investigation Team #2 reported Ops Office clear.

Actual Time	Elapsed Time	Event
13:20:35	7:01	Water mist requested in CPO Living by Repair 2 personnel. DCC personnel reported that water mist was already in BC mode in this space.
13:21:01	7:27	DCO activated water mist in CPO Living in FS mode, since there was a reported fire in this space. Based on the temperatures in the compartment SCS activated water mist in the modified FS mode, where water mist was energized for approximately 45 seconds and de-energized for 15 seconds (on for ~66%)
13:21:25	7:51	Investigators reported CPO Living clear.
13:21:38	8:04	Control Room personnel re-activated and secured E 1-15-1.
13:21:48	8:14	Investigation Team #1 sent to verify fire in CIC.
13:22:22	8:48	Investigators reported fire in Combat Systems Office.
13:22:32	8:58	Repair 2 Comm Operator reported manual fire boundaries in process of being set in Engineering Operations Station.
13:23:09	9:35	SCS identified a Small fire in the Combat Systems Office, based on a report made by on-scene investigators.
13:23:16	9:42	DC Plotter/Comm Operator attempted to contact Investigation Team #1 for status of fire in CIC.
13:23:49	10:15	Investigation Team #2 reported Tomahawk Equipment Room Vestibule clear.
13:24:45	11:11	SCS recommended dispatching Rapid Response Team for indirect attack on Combat Systems.
13:24:53	11:19	SCS detected smoke in Passage 2-15-3-L.
13:24:58	11:24	SCS recommended engaging installed desmoking.
13:25:03	11:29	Communications with Investigation Team #1 were bad. DC Plotter/Comm Operator attempted to contact Investigation Team #1 again for status of fire in CIC.
13:25:15	11:41	SES activated by DCO.
13:25:38	12:04	Investigation Team #2 reported CSMC/Repair 8 clear.

Actual Time	Elapsed Time	Event
13:25:40	12:06	SCS reported smoke cleared in Passage 2-15-3-L.
13:26:19	12:45	DCO requested Repair 2 personnel conduct indirect cooling of CIC.
13:26:37	13:03	SCS detected a Fully-Involved fire in Passage 1-15-4-L.
13:26:45	13:11	Repair 2 Comm Operator reported fire boundary set in Engineering Operations Station.
13:27:02	13:28	DCO requested Repair 2 personnel perform a direct attack of fire in AMR No. 1.
13:27:07	13:33	SCS recommended dispatching an Attack Team to set manual fire boundaries on the main deck, port side passage.
13:27:33	13:59	Investigation Team #1 reported fire in CIC.
13:27:41	14:07	Investigation Team #2 reported fire in AMR No. 1. MMR No. 1 reported clear.
13:28:56	15:22	SCS recommended dispatching the Support Team to set manual fire boundaries forward of CPO Living and also in areas where boundaries were already set.
13:28:57	15:23	SCS recommended dispatching an Attack Team to perform an indirect fire attack of fire in port side passageway.
13:29:18	15:44	DCO sent Investigation Team #2 to investigate port side main deck passage for possible fire.
13:29:54	16:20	Investigators reported Engineering Storeroom door hot.
13:30:10	16:36	Attack Team started the Indirect Attack of CIC from CSMC/Repair 8.
13:30:32	16:58	SCS detected a Small fire in the Engineering Storeroom, based on a report made by on-scene investigation teams.
13:31:02	17:28	DCO requested Investigation Team #1 check CPO Living for possible fire.
13:31:20	17:46	Control Room personnel secured spray fire in Comm Center.
13:31:28	17:54	Repair 2 Comm Operator reported the indirect attack of CIC and the direct attack in AMR No. 1 were in progress.

Actual Time	Elapsed Time	Event
13:31:52	18:18	Control Room personnel re-activated fan E 1-15-1.
13:32:04	18:30	Investigation Team #2 reported no fire outside of CSMC/Repair 8.
13:32:19	18:45	SCS indicated fire cleared in Passage 1-15-4-L.
13:32:27	18:53	Investigation Team #1 could not be reached due to communications problems. DCO requested Investigation Team #2 investigate possible fire in CPO Living.
13:33:57	20:23	SCS detected smoke in Passage 2-15-3-L.
13:34:16	20:42	SCS detected a Medium fire in Access 3-24-1-L.
13:34:22	20:48	Control Room personnel secured fan E 1-15-1.
13:34:33	21:01	SCS switched water mist system from FS mode to BC mode in CPO Living. At this time the system was energized.
13:34:35	21:03	Repair 2 Comm Operator reported indirect attack in CIC completed.
13:34:59	21:25	Fire in CPO Living cleared by DCO.
13:35:06	21:32	SCS secured water mist in CPO Living.
13:35:17	21:43	Control Room personnel secured fan E 1-15-2.
13:35:47	22:13	Water mist de-activated in CPO Living at the request of Investigation Team #1.
13:36:00	22:26	DCO requested Investigation Team #1 confirm the status of the fire in CPO Living.
13:36:04	22:30	DCO requested Repair 2 personnel conduct direct attack of the fire in the Comm Center.
13:36:12	22:38	SCS energized water mist in Tomahawk and Engineering Storeroom, based on elevated temperatures. (On for 33% of cycle). SCS also re-energized water mist in CPO Living in BC mode.
13:37:13	23:39	SCS reported smoke cleared in Passage 2-15-3-L.
13:37:30	23:56	SCS reported smoke detected in Passage 2-15-3-L.

Actual Time	Elapsed Time	Event
13:37:47	24:13	SCS reported smoke cleared in Passage 2-15-3-L.
13:37:59	24:25	Investigation Team #2 attempting to cool Ops Office from Combat Systems.
13:38:32	24:58	Attack Team en-route to Comm Center.
13:38:52	25:18	Investigators reported fire in Ops Office.
13:39:09	25:35	SCS reported a Small fire in Ops Office, based on input from on-scene personnel.
13:39:45	26:11	SCS indicated fire cleared in Combat Systems Office.
13:39:50	26:16	Investigation Team #2 requested that water mist be secured in Ops Office. DC Plotter/Comm Operator asked why the investigators wanted water mist secured. This was not done by the DCO since investigators did not provide reason to secure system.
13:41:05	27:31	Investigation Team #2 reported Ops Office clear.
13:41:09	27:35	SCS indicated fire cleared in Ops Office.
13:41:40	28:06	Investigators reported Engineering Storeroom and CSMC/Repair 8 clear.
13:41:55	28:21	SCS indicated fire cleared in Engineering Storeroom.
13:42:39	29:05	Repair 2 reported the Attack Team restarted indirect cooling of CIC.
13:42:44	29:10	Investigation Team #1 reported Tomahawk Equipment Room is hot, but cooling down.
13:43:34	30:00	SCS reported a Small fire in Tomahawk Equipment Room. It was not clear who actually entered a fire in this compartment, believe that DC Plotter/Comm Operator entered this fire, based on report of hot bulkhead in space.
13:43:46	30:12	Repair 2 Comm Operator reported Class B fire in AMR No. 1 out, reflash watch set. Investigators reported Tomahawk Vestibule clear.
13:43:48	30:14	SCS recommended dispatching an Attack Team to Combat Systems Office to perform an indirect attack on Tomahawk Equipment Room.
13:45:04	31:30	Investigation Team #1 reported MMR No. 1 clear.

Actual Time	Elapsed Time	Event
13:45:44	32:10	DCO cleared fire in Tomahawk Equipment Room; no fire in this compartment, bulkhead is hot.
13:46:43	33:09	Repair 2 Comm Operator reported no flames, but a lot of heat in CIC.
13:47:50	34:16	Investigators reported Combat Systems and Ops Office clear.
13:48:21	34:47	Repair 2 Comm Operator reported that the Attack Team was accessing the Comm Center.
13:48:34	35:00	Investigation Team #1 reported door to CIC hot.
13:49:10	35:36	Investigation Team #2 reported Tomahawk Vestibule clear.
13:49:30	35:56	Direct attack of fire in Comm Center started.
13:50:32	36:58	Investigation Team #1 reported port-side passageway clear.
13:51:05	37:31	Repair 2 reported fire in Comm Center out, reflash watch set.
13:51:35	38:01	Investigators reported Repair 8/CSMC clear.
13:51:39	38:05	SCS secured water mist in Tomahawk Equipment Room.
13:52:00	38:26	Investigation Team #1 sent to investigate CIC for possible fire.
13:52:08	38:34	Repair 2 Comm Operator reported the fire in Comm Center re-flashed. SCS was updated to reflect fire in Comm Center.
13:52:28	38:54	No response from Investigation Team #1 regarding status of CIC, Investigation Team #2 sent to investigate CIC.
13:53:10	39:36	Control Room personnel activated E 1-15-1 and E 1-15-2 fans.
13:53:14	39:40	Repair 2 Comm Operator reported re-flash in Comm Center out.
13:53:58	40:24	Investigators reported door to CIC is hot. Requested permission to cool door.
13:54:26	40:52	DC Watch Supervisor sent Repair 2 personnel to check Radio Transmitter Room and Crew Living for possible fires.

Demonstration: arm3w05 **Date: September 24, 2001**

Actual Time	Elapsed Time	Event
13:55:42	42:08	Investigators cooling door to CIC.
13:57:40	44:06	Test completed.

Demonstration: arm3w06 **Date: September 25, 2001**

Test Description:
Main Space Fire Locations -
- Communications Center – Main spray fire, dog-leg spray fire and wood-crib
- Radio Transmitter Room – Wood crib

Sympathetic Ignition Locations
- Tomahawk Equipment Room – One bin
- Engineering Storeroom – One bin
- Combat Systems – One bin
- CPO Living – Bedding materials

Firemain Rupture Location
- None

Progressive Flooding
- MMR No. 1

Actual Time	Elapsed Time	Event
12:56:35	0:00	Control Room personnel ignited spray fires in Comm Center and initiated damage to instrumentation.
12:56:36	0:01	SCS detected a Fully-Involved fire in Crew Living, based on bad sensor data and the predicted damage area.
12:56:39	0:04	SCS detected a Fully-Involved fire in the Comm Center, based on bad sensor data and the predicted damage area.
12:56:40	0:05	SCS detected Fully-Involved fires in the Radio Transmitter Room and the Tomahawk Equipment Room Vestibule, based on bad sensor data and the predicted damage area.
12:56:42	0:07	SCS activated water mist in BC mode CPO Living. Water mist **was not** energized at this time.
12:56:56	0:21	Safety Team personnel ignited pan for wood crib in Radio Transmitter Room.
12:56:58	0:23	SCS detected a Fully-Involved fire in CIC, based on bad sensor data and the predicted damage area.
12:57:06	0:31	DCO reviewed locations of fires with the investigators and sent them out to verify damage.
12:57:07	0:32	SCS activated water mist in BC mode in the remaining APDA compartments – CSMC/Repair 8, Combat Systems, Ops Office, Tomahawk and Engineering Storeroom. Water mist **was not** energized at this time.

Actual Time	Elapsed Time	Event
12:57:33	0:58	SCS recommended dispatching an Attack Team to set manual fire boundaries in the passageways on the 2nd deck. At this time, the DC Watch Supervisor requested personnel set boundaries port and starboard sides, 2nd deck. The Casualty Coordinator dispatched the Support Team to set boundaries, other teams were told to standby.
12:58:21	1:46	SCS recommended dispatching the Support Team to cut an access to the Comm Center and sending an Attack Team to CSMC/Repair 8 to perform an indirect fire attack of CIC.
12:58:33	1:58	SCS recommended dispatching an Attack Team to the Comm Center to perform a direct attack of the fire in this space.
12:59:00	2:25	SCS detected a Medium fire in CPO Living, based on elevated temperatures.
12:59:09	2:34	SCS energized water mist in CPO Living, based on elevated temperatures.
12:59:20	2:45	Control Room personnel secured fan E1-15-1.
12:59:21	2:46	DCO requested that Investigation Team #1 check MMR No. 1 and AMR No. 1 after initial check of main spaces.
12:59:31	2:56	DC Watch Supervisor requested personnel set manual fire boundary forward of CPO Living.
13:00:00	3:25	Sympathetic ignition of bin in Tomahawk Equipment Room.
13:00:25	3:50	SCS switched water mist in CPO Living from BC mode to modified FS mode. At this time water mist **was** energized and the system was pulsed on and off at 12 second intervals.
13:00:30	3:55	Repair 2 reported that the manual fire boundaries on the 2nd deck were set.
13:00:38	4:03	SCS energized water mist in Tomahawk, based on elevated temperatures.
13:00:41	4:06	SCS detected a Large fire in the Tomahawk Equipment Room.
13:00:53	4:18	Investigators reported that the door to CIC was hot.
13:01:16	4:41	SCS switched water mist system in Tomahawk Equipment Room from BC mode to modified FS mode. At this time water mist was pulsed on and off at 12 second intervals.

Actual Time	Elapsed Time	Event
13:01:18	4:43	DCO sent Investigation Team #2 to check Tomahawk Equipment Room for possible fire.
13:02:42	6:07	DCO requested that Investigation Team #2 also check Tomahawk Vestibule for possible fires.
13:03:48	7:13	Investigators reported that the door to AMR No. 1 was jammed and cool.
13:03:56	7:21	DCO reminded Investigation Team #1 to check MMR No. 1.
13:04:05	7:30	Investigation Team #2 reported that Tomahawk Vestibule was clear.
13:04:11	7:36	SCS reported fire cleared in Tomahawk Vestibule.
13:04:52	8:17	DCO confirmed that the Engineering Storeroom was clear using available video of this space.
13:04:59	8:24	Investigators reported that Combat Systems office was smoky.
13:05:57	9:22	Investigation Team #1 reported to be accessing AMR No. 1.
13:06:18	9:43	Investigation Team #2 sent to check CPO Living for possible fire.
13:06:30	9:55	DCO ordered indirect attack of CIC.
13:06:38	10:03	Investigators reported that Ops Office was hot.
13:07:24	10:49	Investigators reported that AMR No. 1 escape trunk was flooded. DCO updated SCS to reflect this report.
13:07:35	11:00	SCS detected flooding in AMR No. 1, based on reports made by Investigators. Repair 2 personnel reported smoke in the passageways on the 2nd deck. The Casualty Coordinator ordered that the smoke curtains be rigged and requested that DCC activate SES.
13:08:00	11:25	DCO activated SES.
13:08:33	11:58	DC Watch Supervisor informed the Casualty Coordinator of flooding in AMR No. 1.
13:08:38	12:03	Casualty Coordinator dispatched the Attack Team to contain flooding in AMR No. 1.
13:09:07	12:32	DC Watch Supervisor requested that personnel man the fire boundary in the

Actual Time	Elapsed Time	Event
		Engineering Storeroom, since water mist did not appear to be activating.
13:09:34	12:59	DCO requested that Investigation Team #2 report the status of CPO Living.
13:09:35	13:00	Flooding in MMR No. 1 started by test team personnel.
13:10:00	13:25	Indirect attack fire of CIC started.
13:10:30	13:55	Investigators reported that the forward bulkhead in CPO Living was hot.
13:10:37	14:02	SCS recommended dispatching an Attack Team to Combat Systems Office to perform an indirect attack of fire in Tomahawk Equipment Room from above.
13:10:40	14:05	Spray fire in Comm Center out.
13:11:03	14:28	Investigators reported fire in CIC.
13:11:11	14:36	Investigators reported that there was no fire in CPO Living.
13:11:22	14:47	SCS reported fire cleared in CPO Living.
13:11:32	14:57	Control Room personnel activated fan E1-15-1.
13:11:40	15:05	Investigators requested that water mist be secured in the Tomahawk Equipment Room.
13:11:48	15:13	SCS secured water mist in Tomahawk Equipment Room.
13:12:38	16:03	Control Room personnel secured fan E1-15-1.
13:12:42	16:07	Investigators reported that Tomahawk Equipment Room was clear, with 4” of water on the deck.
13:12:56	16:21	DCO cleared fire in Tomahawk Equipment Room. Re-activated water mist in BC mode. Attempted to activate water mist in Engineering Storeroom, however system did not respond.
13:13:45	17:10	DC Watch Supervisor requested an update on the status flooding in AMR No. 1.
13:14:05	17:30	Repair 2 reported that flooding was in MMR No. 1, not AMR No. 1. DCO updated SCS to reflect this report. At this time, the Attack Team was

Actual Time	Elapsed Time	Event
		working on containing flooding in MMR No. 1.
13:14:30	17:55	Control Room personnel secured fan E1-15-2.
13:14:38	18:03	Repair 2 reported that there was no fire in CIC, fire in Comm Center.
13:14:51	18:16	DCO requested that status of fire in Tomahawk Equipment Room.
13:15:50	19:15	SCS re-activated water mist in modified FS mode in the Tomahawk Equipment Room, based on request made by on-scene personnel. At this time water mist was energized.
13:15:56	19:21	Investigators reported that Combat System Office was clear.
13:16:13	19:38	DCO switched the water mist system in Tomahawk Equipment Room back to BC mode.
13:16:30	19:55	Sympathetic ignition in Combat Systems Office
13:16:32	19:57	Investigation Team #2 reported Ops Office clear.
13:17:05	20:30	DCO confirmed fire in Combat Systems using available video.
13:17:18	20:43	Investigation Team #1 sent to check fire in Combat Systems. The Repair 2 Comm Operator reported that the indirect attack had been secured.
13:18:02	21:27	DCO reported that the Attack Team needed to perform a direct attack of the fire in Comm Center, however needed to gain access to this compartment first, since all accesses were hot and jammed.
13:18:56	22:21	DC Watch Supervisor requested status of boundary in Engineering Storeroom. Repair 2 reported that the manual fire boundary was set.
13:19:21	22:46	Investigators reported a small fire in Combat Systems.
13:19:35	23:00	Investigators reported that the fire in Combat Systems had been extinguished.
13:19:46	23:11	Repair 2 reported that flooding in MMR No. 1 was minimal, Attack Team in the process of making repairs.
13:20:07	23:32	Repair 2 reported that the Support Team was en-route to access Comm Center.

Actual Time	Elapsed Time	Event
13:23:51	27:16	Repair 2 reported that access to the Comm Center was gained. Attack Team in the process of entering the space.
13:24:52	28:17	Repair 2 reported that the Attack Team entered Comm Center.
13:25:27	28:52	Repair 2 reported that plugging in MMR No. 1 50% complete.
13:25:45	29:10	Investigators reported heavy smoke, no fire in Combat Systems.
13:26:08	29:33	Repair 2 reported Class A fire in Comm Center.
13:26:09	29:34	Direct attack of Comm Center started.
13:26:40	30:05	Flooding secured.
13:26:53	30:18	Repair 2 reported that plugging completed in MMR No. 1.
13:26:56	30:21	Investigation Team #2 reported that the stbd door to CIC was hot and jammed.
13:27:13	30:38	Control Room personnel observed fire in Radio Transmitter Room. Attack Team observed to be extinguishing this fire with hose.
13:28:30	31:55	Repair 2 reported that plugging was completed, 6” water in bilge, personnel started de-watering.
13:29:39	33:04	Investigation Team #1 reported Engineering Storeroom clear, forward bulkhead hot.
13:30:10	33:35	Investigators reported Tomahawk Equipment Room clear, 4” water on deck.
13:31:10	34:35	Control Room personnel activated fans E1-15-1 and E1-15-2.
13:31:59	35:24	Investigators reported AMR No. 1 forward bulkhead cool.
13:34:16	37:41	SCS reported fire cleared in Tomahawk Equipment Room and CIC.
13:34:25	37:50	SCS reported flooding detected in MMR No. 1.
13:35:41	39:06	Repair 2 reported fire out in Comm Center and adjacent spaces.
13:35:49	39:14	SCS reported fire cleared in Comm Center.

Actual Time	Elapsed Time	Event
13:35:58	39:23	SCS reported fire cleared in Crew Living.
13:36:03	39:28	SCS reported fire cleared in Radio Transmitter Room.
13:36:30	39:55	Test completed.

Test Description:
Main Space Fire Locations -
- Communications Center – Main spray fire, dog-leg spray fire and wood-crib
- Radio Transmitter Room – Wood crib

Sympathetic Ignition Location
- Tomahawk Equipment Room – One bin
- Engineering Storeroom – One bin
- Combat Systems – One bin
- CPO Living – Bedding materials

Firemain Rupture Location
- 2nd Deck Stbd Passage

Progressive Flooding
- MMR No. 1

Actual Time	Elapsed Time	Event
13:23:15	0:00	Control Room personnel activated the spray fires in the Comm Center and initiated damage to selected instrumentation.
13:23:20	0:05	SCS detected Fully-Involved fires in the Comm Center, Radio Transmitter Room and Tomahawk Equipment Room Vestibule, based on bad sensor data and the predicted damage area.
13:23:26	0:11	Safety Team personnel ignited pan for wood crib in Radio Transmitter Room.
13:23:32	0:17	SCS detected a Fully-Involved fire in CIC, based on bad sensor data and the predicted damage area.
13:23:34	0:19	SCS detected a Fully-Involved fire in Crew Living, based on bad sensor data and the predicted damage area.
13:23:42	0:27	SCS activated water mist in BC mode in the APDA compartments – CPO Living, Tomahawk, Engineering Storeroom, Combat Systems, Ops Office and CSMC. Water mist **was not** energized at this time.
13:23:46	0:31	Investigation Teams reported to DC Central. DCO informed teams of possible fires in Comm Center and CIC.
13:24:15	1:00	Investigation Teams were dispatched to confirm damage.
13:24:26	1:11	Control Room personnel initiated rupture on 2nd deck, starboard passage.
13:24:28	1:13	SCS recommended dispatching the Support Team to set manual fire boundaries in the passageways on the 2nd deck.
13:24:32	1:17	DC Watch Supervisor ordered boundaries to be set on the port and starboard side on the 2nd deck.

Actual Time	Elapsed Time	Event
13:24:43	1:28	SCS detected a potential fire main rupture, between valves 2-17-1 and 1-26-2. SCS began to close the appropriate valves to isolate the rupture.
13:25:10	1:55	DCO utilized video to observe rupture in Passage 2-15-3.
13:25:23	2:08	SCS reported that the fire main rupture had been isolated.
13:25:33	2:18	SCS energized water mist in CPO Living in BC mode. At this time water mist, was energized for ~ 30 seconds and de-energized for ~ 1 minute 30 seconds.
13:25:37	2:22	SCS detected a Medium fire in CPO Living, based on elevated temperatures in the space.
13:26:06	2:51	Investigators reported 4" of water on deck – 2nd deck, starboard passage due to fire main rupture.
13:26:15	3:00	SCS identified the fire plugs that were unusable due to the fire main rupture.
13:26:33	3:18	SCS detected a Medium fire in the Engineering Storeroom, based on elevated temperatures in the compartment.
13:26:37	3:22	Investigators reported that the port side door to CIC was hot and jammed.
13:26:50	3:35	Sympathetic ignition of bin in Tomahawk Equipment Room.
13:26:51	3:36	Control Room personnel secured fuel for dog-leg spray fire in Comm Center.
13:27:00	3:45	Repair 2 personnel noted that the Support Team was attempting to set manual fire boundaries on the 2nd deck. The unusable fire plugs were not reported, therefore boundary men were not sure which part of the fire main was available for setting boundaries.
13:27:16	4:01	DCO requested that the investigators check for possible fire in CPO Living.
13:27:21	4:06	SCS energized water mist in Tomahawk Equipment Room and Engineering Storeroom in BC mode, based on elevated temperatures in the compartment.
13:27:28	4:13	SCS detected a Medium fire in the Tomahawk Equipment Room, based on elevated temperatures in the compartment.
13:27:55	4:40	Investigators reported forward bulkhead in Combat Systems was hot.

Actual Time	Elapsed Time	Event
13:28:10	4:55	SCS switched the water mist system in Tomahawk to modified FS mode. At this time, water mist was generally pulsed on and off at 20 second intervals.
13:28:27	5:12	Investigators reported fire in Combat Systems.
13:28:39	5:24	SCS reported a Small fire in the Combat Systems, based on a report made by investigators.
13:28:43	5:28	SCS switched the water mist system in Combat Systems and Engineering Storeroom to modified FS mode, where water mist was pulsed on and off at 20 second intervals.
13:28:44	5:29	Investigators reported forward bulkhead in Ops Office was hot.
13:29:13	5:58	DCO sent Investigation Team #2 to check for fire in the Tomahawk Vestibule.
13:30:21	7:06	Repair 2 confirmed stbd boundary set.
13:30:30	7:15	Investigation Team #1 reported that the door to AMR No. 1 was cool.
13:30:38	7:23	DCO asked the investigators if AMR No. 1 was accessible.
13:31:05	7:50	Investigators reported the port side passage was clear. Repair 2 requested activation of SES.
13:31:20	8:05	DCO activated SES.
13:31:37	8:22	Repair 2 reported that boundaries were set on the port and stbd side, 2nd deck.
13:32:21	9:06	Investigators reported 4' of water in the escape trunk for AMR No. 1.
13:32:36	9:21	DCO entered flooding in AMR No. 1 into SCS, based on report made by investigators.
13:32:37	9:22	SCS indicated flooding in AMR No. 1.
13:32:47	9:32	Investigators reported deck in CSMC/Repair 8 was hot.
13:32:56	9:41	DCO asked investigators if there was a fire in CSMC/Repair 8. Investigators reported no fire in the space.
13:33:29	10:14	Investigation Team #2 was sent to investigate possible fire in CPO Living.

Actual Time	Elapsed Time	Event
13:33:32	10:17	SCS switched the water mist system from BC mode to FS mode in CPO Living.
13:33:50	10:35	Investigators reported that water mist had been activated in the Engineering Storeroom. No fire reported in this space.
13:34:42	11:27	SCS switched water mist in the Engineering Storeroom from FS mode to BC mode.
13:34:46	11:31	Investigators reported that CPO Living was hot.
13:34:59	11:44	Report made by investigators that flooding had occurred on the lower level of MMR No. 1. This information was entered into the SCS by the DCO.
13:35:20	12:05	DCO ordered indirect cooling of CIC from CSMC/Repair 8. At this time the Casualty Coordinator, dispatched Attack Team #1
13:35:26	12:11	SCS indicated flooding in MMR No. 1.
13:35:30	12:15	DCO sent an Attack Team to contain flooding in MMR No. 1, since AMR No. 1 was not accessible.
13:35:57	12:42	DCO requested the status of CPO Living.
13:36:32	13:17	Investigators reported that the forward bulkhead in the Engineering Storeroom was hot.
13:37:00	13:45	SCS detected a potential fire main rupture, between valves 2-23-1 and 1-26-2. SCS began to close the appropriate valves to isolate the rupture.
13:37:03	13:48	Investigators reported no fire in the Engineering Storeroom.
13:37:08	13:53	DCO requested status of the Tomahawk Equipment Room and Tomahawk Vestibule.
13:37:27	14:12	Investigators reported deck in CPO Living was hot, but no fire.
13:37:38	14:23	SCS identified the fire plugs that were unusable due to the fire main rupture.
13:37:47	14:32	Investigators reported no fire in the Tomahawk Equipment Room.
13:37:50	14:35	SCS reported that the fire main rupture had been isolated.

Actual Time	Elapsed Time	Event
13:37:51	14:36	SCS indicated Fire Cleared in the Tomahawk Equipment Room, based on a report made by on-scene personnel. Additionally, SCS detected a fire in CPO Living again.
13:38:04	14:49	SCS secured water mist in Combat Systems, Tomahawk Equipment Room and the Engineering Storeroom.
13:38:16	15:01	The DCO re-activated water mist in FS mode in the Engineering Storeroom.
13:38:21	15:06	The DCO re-activated water mist in FS mode in the Combat Systems.
13:38:32	15:17	SCS re-energized water mist in modified FS mode in Combat Systems and Engineering Storeroom. For the systems in modified FS mode, the system was pulsed on and off at 20 second intervals. Water mist was engaged in BC mode in Tomahawk.
13:38:40	15:25	SCS reported Fire Cleared in the Engineering Storeroom.
13:38:54	15:39	Investigators reported door to Tomahawk Vestibule was jammed, but not hot.
13:39:17	16:02	Repair 2 reported that there was a fragmented bulkhead in MMR No. 1, plugging in progress.
13:39:29	16:14	SCS switched water mist from FS mode to BC mode in CPO Living.
13:39:34	16:19	SCS reported Fire Cleared in CPO Living.
13:39:44	16:29	Repair 2 reported indirect cooling in progress, no apparent fire in CIC.
13:39:50	16:35	SCS secured water mist in CPO Living.
13:40:58	17:43	Investigators reported no fire in Combat Systems Office.
13:41:02	17:47	SCS reported Fire Cleared in Combat Systems Office.
13:41:07	17:52	SCS switched water mist in Combat Systems from FS mode to BC mode.
13:41:09	17:54	Investigators reported starboard door to CIC hot and jammed.
13:41:28	18:13	Investigation Team #2 sent to check Tomahawk Vestibule.
13:41:31	18:16	SCS switched water mist from FS mode to BC mode in the Engineering

Actual Time	Elapsed Time	Event
		Storeroom.
13:42:24	19:09	SCS energized water mist in Tomahawk, based on elevated temperatures.
13:42:26	19:11	Attack Team reported fire in Comm Center. Control Room personnel secured fan E1-15-1.
13:42:40	19:25	Control Room personnel secured fan E1-15-2.
13:43:23	20:08	Investigation Team #2 reported no fire in Tomahawk Vestibule.
13:43:37	20:22	SCS reported Fire Cleared in the Tomahawk Vestibule.
13:43:38	20:23	Investigators reported forward bulkhead hot in Engineering Storeroom.
13:44:09	20:54	Repair 2 reported plugging in MMR No. 1 50% complete, ~ 6" water in bilge – slowly rising.
13:44:59	21:44	DCO ordered indirect attack of CIC to be discontinued. Requested that personnel conduct direct attack of Comm Center.
13:45:35	22:20	Investigation Team #1 sent to check Comm Center access on starboard side.
13:46:03	22:48	DCO requested Attack Team to standby, ready to conduct direct attack of Comm Center when space was accessible.
13:46:56	23:41	Repair 2 reported plugging in MMR No. 1 75% complete.
13:47:00	23:45	Personnel still conducting indirect cooling.
13:47:12	23:57	Investigation Team #2 reported no fire in CPO Living.
13:48:15	25:00	Repair 2 requested permission to de-water MMR No. 1.
13:48:35	25:20	DCO attempted to reach Investigation Team #1 regarding status of Comm Center access.
13:48:40	25:25	SCS re-energized water mist in BC mode in CPO Living.
13:49:48	26:33	Investigators reported scuttle to Comm Center is hot. DCO asked if scuttle was accessible.

Actual Time	Elapsed Time	Event
13:50:14	26:59	Repair 2 reported that stbd door to Comm Center was hot and jammed. DCO ordered Support Team to report to the Comm Center, stbd side and standby with exothermic torch.
13:50:54	27:39	Investigators reported forward bulkhead in Ops Office hot.
13:51:05	27:50	DCO requested that the Attack Team standby to re-commence indirect attack of CIC, if needed.
13:51:30	28:15	Exothermic torch used to gain access to Comm Center.
13:51:37	28:22	Repair 2 reported plugging in MMR No. 1, 100% complete. Water level in MMR No. 1 is decreasing.
13:52:22	29:07	Investigation Team #1 reported Tomahawk Vestibule clear.
13:52:28	29:13	De-watering of MMR No. 1 completed, flood watch set. DCO cleared flooding in MMR No. 1 on SCS screen.
13:53:12	29:57	DCO gave permission to Attack Team to conduct indirect attack in CIC, when they deemed necessary. DCO also noted that when the direct attack of the Comm Center was started, the Attack Team performing the indirect attack from CIC should leave the space.
13:54:41	31:26	Repair 2 reported access made to the Comm Center. Attack Team entering space.
13:55:02	31:47	DC Watch Supervisor confirmed that indirect attack in CIC had been secured.
13:55:44	32:29	Repair 2 reported fire out in Comm Center, re-flash watch set.
13:55:56	32:41	SCS reported Fire Cleared in the Comm Center, based on reports made by the Attack Team.
13:56:19	33:04	SCS secured water mist in Tomahawk.
13:56:51	33:36	DC Watch Supervisor confirmed no fire in CIC, based on Attack Team performing indirect attack from this space.
13:57:03	33:48	Repair 2 sent personnel to Crew Living and Radio Transmitter Room to confirm status of fires in these compartments.
13:57:09	33:54	SCS reported Fire Cleared in CIC, based on reports made by on-scene personnel.

Actual Time	Elapsed Time	Event
13:57:24	34:09	SCS secured water mist in Combat Systems.
13:57:30	34:15	Control Room personnel activated fans E1-15-1 and E1-15-2.
13:57:40	34:25	Repair 2 reported Class A fire in Radio Transmitter Room.
13:57:54	34:39	Repair 2 reported Class A fire out in Radio Transmitter Room.
13:57:59	34:44	Investigation Team #1 initially sent to CPO Living to check for possible fire in this compartment.
13:58:05	34:50	Investigation Team #1 sent to Crew Living – not CPO Living – to check for fire.
13:58:09	34:54	SCS reported Fire Cleared in the Radio Transmitter Room, based on report made by Repair 2.
13:58:30	35:15	Investigation Team #1 reported CPO Living clear. DCO sent team to check Crew Living. SCS secured water mist in Engineering Storeroom.
13:59:22	36:07	Repair 2 requested permission to conduct direct attack in Crew Living.
14:00:39	37:24	Repair 2 reported overhaul of fire in Comm Center completed.
14:01:24	38:09	Investigators reported Attack Team entering Crew Living.
14:01:52	38:37	SCS detected smoke in the Passage 2-9-0, outside of Repair 2.
14:02:56	39:41	SCS reported smoke cleared in Passage 2-9-0.
14:05:20	42:05	SCS detected smoke in the Passage 2-9-0, outside of Repair 2.
14:06:19	43:04	Repair 2 reported no fire in Crew Living.
14:06:27	43:12	SCS reported Fire Cleared in Crew Living.
14:06:55	43:40	Test completed.

Demonstration: arm3w08 **Date: September 27, 2001**

Test Description:
Main Space Fire Locations -
- Communications Center – Main spray fire, dog-leg spray fire and 2 large wood-cribs
- Radio Transmitter Room – Wood crib

Sympathetic Ignition Location
- Tomahawk Equipment Room – One bin
- Engineering Storeroom – One bin
- Combat Systems – Two bins
- CPO Living – Bedding materials

Firemain Rupture Location
- Operations Office

Actual Time	Elapsed Time	Event
13:53:37	0:00	Control Room personnel ignited spray fires in Comm Center and initiated damage to instrumentation. Safety team personnel ignited fuel pan for wood crib in Radio Transmitter Room.
13:53:45	0:08	SCS detected Fully-Involved fires in the Comm Center and Radio Transmitter Room, based on bad sensor data and the predicted damage area.
13:53:53	0:16	SCS detected a Fully-Involved fire in the CIC, based on bad sensor data and the predicted damage area.
13:53:58	0:21	SCS detected a Fully-Involved fire in Crew Living, based on bad sensor data and the predicted damage area.
13:54:04	0:27	SCS activated water mist in BC mode in the APDA compartments - CSMC/Repair 8, Tomahawk Equipment Room, CPO Living, Combat Systems Office, Ops Office, and the Engineering Storeroom.
13:54:23	0:46	The DCO reported damaged areas to investigators and sent them out to verify damage.
13:54:33	0:56	SCS detected a Fully-Involved fire in CSMC/Repair 8 based on bad sensor data and the predicted damage area.
13:54:43	1:06	SCS switched water mist in CSMC/Repair 8 from BC mode to FS mode.
13:54:44	1:07	DC Watch Supervisor requested that the Support Team set manual fire boundaries on the port and starboard sides, 2nd deck.
13:55:00	1:23	Control Room personnel initiated fire main rupture in Ops Office.
13:55:09	1:32	SCS secured the water mist system from FS mode in CSMC/Repair 8.
13:55:34	1:57	SCS re-activated the water mist system in CSMC/Repair 8 in FS mode.

Actual Time	Elapsed Time	Event
13:55:55	2:18	Control Room personnel secured rupture.
13:56:12	2:35	Repair 2 reported personnel sent to set manual fire boundaries on 2nd deck.
13:56:21	2:44	DCO utilized video of CSMC/Repair 8 to verify status of fire in this compartment. No fire was observed, switched status to “Fire Out”. The DCO switched water mist switched from FS mode to BC mode.
13:56:31	2:54	SCS isolated the fire main rupture.
13:56:43	3:06	SCS reported fire cleared in CSMC/Repair 8.
13:56:54	3:17	SCS switched water mist from FS mode to BC mode in CSMC/Repair 8. At this time the system was not energized.
13:57:16	3:39	Repair 2 reported manual fire boundaries were set on the 2nd deck.
13:57:43	4:06	Investigators reported the stbd door to CIC was jammed and warm.
13:57:48	4:11	SCS energized water mist in CSMC/Repair 8. At this time the system was in BC mode, where the system was energized for 60 seconds and de-energized for 2 minutes, 20 seconds.
13:57:50	4:13	Control Room personnel secured fan E1-15-1.
13:57:54	4:17	DC Watch Supervisor reported fire plugs out of service to Repair 2.
13:58:04	4:27	Investigators reported that port door to CIC was hot and jammed.
13:59:00	5:23	Sympathetic ignition of bin in Engineering Storeroom.
13:59:05	5:28	DCO utilized video to confirm fire in Engineering Storeroom and attempted to switch the water mist system in this compartment to FS mode.
13:59:20	5:43	Control Room personnel activated fan E1-15-1.
13:59:40	6:03	Safety team personnel ignited bedding materials in CPO Living.
13:59:45	6:08	DCO sent Investigation Team #2 to verify fire in the Engineering Storeroom.
13:59:47	6:10	Fire reported in Comm Center.

Actual Time	Elapsed Time	Event
13:59:50	6:13	SCS detected a Medium fire in the Engineering Storeroom, based on elevated temperatures.
14:00:10	6:33	Investigators reported that the Combat Systems Office was clear.
14:00:19	6:42	Investigators reported that the Ops Office was clear.
14:00:28	6:51	DCO requested that the Attack Team start the indirect attack of CIC.
14:00:35	6:58	SCS switched water mist in the Engineering Storeroom from BC mode to FS mode.
14:00:42	7:05	SCS detected a Medium fire in the Tomahawk Equipment Room, based on elevated temperatures.
14:01:04	7:27	SCS energized water mist in BC mode in the Tomahawk Equipment Room. At this time water mist was energized for 60 seconds and de-energized for 2 minutes, 40 seconds.
14:01:06	7:29	Investigators reported the Tomahawk Equipment Room Vestibule was clear.
14:01:26	7:49	DCO sent Investigation Team #2 to check for possible fire in Tomahawk Equipment Room.
14:01:34	7:57	SCS switched water mist to modified FS mode in the Engineering Storeroom. At this time the system was not energized.
14:01:35	7:58	Investigators reported fire in CPO Living.
14:01:41	8:04	SCS detected a Medium fire in CPO Living, based on elevated temperatures.
14:01:51	8:14	Control Room personnel secured fan E1-15-1.
14:02:03	8:26	SCS secured water mist from BC mode in CPO Living. Water mist was energized in modified FS mode in the Engineering Storeroom. At this time water mist pulsed on and off for ~ 30 seconds.
14:02:04	8:27	DC Watch Supervisor requested that the Support Team establish manual fire boundaries in front of the Repair 2 passage.
14:02:15	8:38	Sympathetic ignition of bin in Combat Systems Office.
14:02:33	8:56	SCS activated water mist in FS mode in CPO Living.

Actual Time	Elapsed Time	Event
14:02:36	8:59	Fire in Combat Systems Office observed by DCO, using available video of the compartment.
14:02:46	9:09	Investigation Team #2 sent to investigate fire in Combat Systems Office.
14:02:55	9:18	DCO activated SES.
14:02:59	9:22	Investigators reported Repair 8 deck hot.
14:03:49	10:12	Investigators reported no fire in Tomahawk Equipment Room.
14:04:01	10:24	DC Watch Supervisor requested a manual fire boundary aft of the Engineering Storeroom.
14:04:10	10:33	SCS reported fire cleared in the Tomahawk Equipment Room, based on report made by on-scene investigators.
14:04:38	11:01	Investigators reported fire in Combat Systems Office was out.
14:04:41	11:04	SCS reclassified the fire in CPO Living as a Large fire.
14:04:56	11:19	Investigation Team #2 sent to check possible fire in CPO Living.
14:06:00	12:23	DCO switched the water mist system in CPO Living to BC mode.
14:06:05	12:28	SCS switched the water mist system from FS mode to BC mode in CPO Living.
14:06:23	12:46	DCO observed Engineering Storeroom still on fire, based on video.
14:06:35	12:58	Personnel requested that water mist be secured in the Engineering Storeroom.
14:06:43	13:06	DCO secured water mist system in Engineering Storeroom.
14:07:07	13:30	SCS secured water mist in Engineering Storeroom.
14:07:35	13:58	DCO switched water mist in Engineering Storeroom from FS mode to BC mode.
14:08:10	14:33	SCS re-activated water mist in the Engineering Storeroom in modified FS mode. At this time the system was energized, and was pulsed on and off at 30 second intervals. SCS also energized the water mist in BC mode in CPO Living.

Actual Time	Elapsed Time	Event
14:08:12	14:35	DCO dispatched an Attack Team to CSMC/Repair 8 on conduct indirect attack of CIC.
14:08:21	14:44	Fire reported out in Engineering Storeroom.
14:08:55	15:18	Investigators reported fire in CPO Living.
14:09:00	15:23	The DCO switched water mist in CPO Living from BC mode to FS mode to try to cool down the space.
14:09:12	15:35	SCS switched the water mist system in CPO Living from BC mode to FS mode.
14:09:49	16:12	Investigators reported MMR No. 1 clear.
14:09:58	16:21	Fire still observed in Engineering Storeroom by the DCO using video.
14:10:58	17:21	Investigators reported the stbd door to CIC was hot and jammed.
14:11:02	17:25	DCO requested that the investigators determine if the Comm Center was accessible.
14:11:10	17:33	Investigators reported the port side door to the CIC was hot and jammed. DCO requested that the Support Team be sent to gain access to the Comm Center.
14:12:00	18:23	Control Room personnel secured spray fire in Comm Center. Attack Team started indirect cooling of CIC from CSMC/Repair 8
14:12:53	19:16	DC Watch Supervisor requested status of manual fire boundaries aft of FR 29 on the 3rd deck.
14:14:27	20:50	Repair 2 reported that the manual boundary on the 3rd deck, aft of FR 29 was in the process of being set.
14:15:19	21:42	SCS detected a Fully-Involved fire in Combat Systems Office, based on bad sensor data. Investigators reported that the access to the Comm Center was hot and jammed.
14:15:49	22:12	Repair 2 reported that the manual boundary on the 3rd deck, aft of FR 29 was set.
14:16:00	22:23	Fire in Engineering Storeroom observed out, based on video.

Actual Time	Elapsed Time	Event
14:16:11	22:34	Investigators reported Tomahawk Equipment Room clear.
14:16:22	22:45	Attack Team still performing indirect attack.
14:16:45	23:08	Control Room personnel secured fan E1-15-1.
14:16:47	23:10	SCS reported Fire Cleared in the Engineering Storeroom.
14:17:02	23:25	DCO requested the Support Team to gain access to Comm Center. The DCO reminded personnel that the direct attack should not be started until the indirect attack was secured.
14:17:32	23:55	Control Room personnel secured fan E1-15-2. SCS displayed new indication of fire in Combat Systems Office. DCO sent Investigation Team #2 to check this compartment.
14:18:32	24:55	Support Team en-route to Comm Center.
14:19:13	25:36	Investigation Team #2 reported Combat Systems Office clear.
14:19:15	25:38	Control Room personnel activated fan E1-15-2.
14:19:32	25:55	DCO sent Investigation Team #2 to check elevated temperatures in CPO Living.
14:19:33	25:56	SCS reported fire cleared in Combat Systems Office.
14:19:39	26:02	Investigators reported Ops Office clear.
14:20:36	26:59	DC Watch Supervisor informed Casualty Coordinator that the manual fire boundary on the 3rd deck, aft of FR 29 could be removed.
14:20:44	27:07	Investigation Team #2 reported CPO Living clear.
14:21:24	27:47	SCS reported fire cleared in CPO Living.
14:21:39	28:02	DCO switched water mist system in CPO Living from FS mode to BC mode.
14:21:47	28:10	Support Team gained access to Comm Center. Indirect attack secured. DC Watch Supervisor requested that an Attack Team be sent to the Comm Center to conduct a direct attack.

Actual Time	Elapsed Time	Event
14:23:15	29:38	Investigators reported Tomahawk Vestibule clear.
14:24:02	30:25	Investigation Team #1 reported fire in Comm Center.
14:24:09	30:32	DCO re-activated water mist in BC mode in CPO Living.
14:24:18	30:41	Investigators reported Combat Systems Office and Ops Office - deck hot.
14:25:50	32:13	Direct attack of fire Comm Center started. Control Room personnel secured fans E1-15-1 and E1-15-2.
14:26:44	33:07	Investigators reported Tomahawk Equipment Room clear.
14:27:11	33:34	Repair 2 reported fire in Comm Center out.
14:27:27	33:50	Repair 2 reported Class A fire in Radio Transmitter Room.
14:27:30	33:53	SCS reported fire cleared in Comm Center.
14:28:25	34:48	On-scene personnel reported fire out in Radio Transmitter Room.
14:28:35	34:58	Fire reported out in Radio Transmitter Room.
14:29:09	35:32	SCS reported fire cleared in Radio Transmitter Room.
14:29:12	35:35	Attack Team reported to be investigating potential fire in Crew Living.
14:29:51	36:14	DCO requested that Investigation Team #2 check for possible fire in CIC using scuttle in Repair 8, since both accesses to CIC were jammed.
14:30:02	36:25	Control Room personnel activated fans E1-15-1 and E1-15-2. Fire in Radio Transmitter Room re-flashed.
14:30:17	36:40	SCS energized water mist in Ops Office in BC mode. At this time the system was energized for 60 seconds and de-energized for 2 minutes 40 seconds.
14:31:00	37:23	Extinguished fire in Radio Transmitter Room.
14:32:13	38:36	Investigation Team #2 reported no fire in CIC.
14:32:37	39:00	SCS reported fire cleared in CIC.

Actual Time	Elapsed Time	Event
14:33:11	39:34	DC Watch Supervisor requested that Repair 2 report the status of the investigation of possible fire in Crew Living.
14:35:08	41:31	Repair 2 reported that reflash watch was set in Comm Center and Radio Transmitter Room. Personnel still investigating Crew Living.
14:41:09	47:32	Repair 2 reported no fire in Crew Living.
14:41:45	48:08	SCS reported fire cleared in Crew Living.
14:42:00	48:23	Test completed.

Appendix M – Selected Test Data

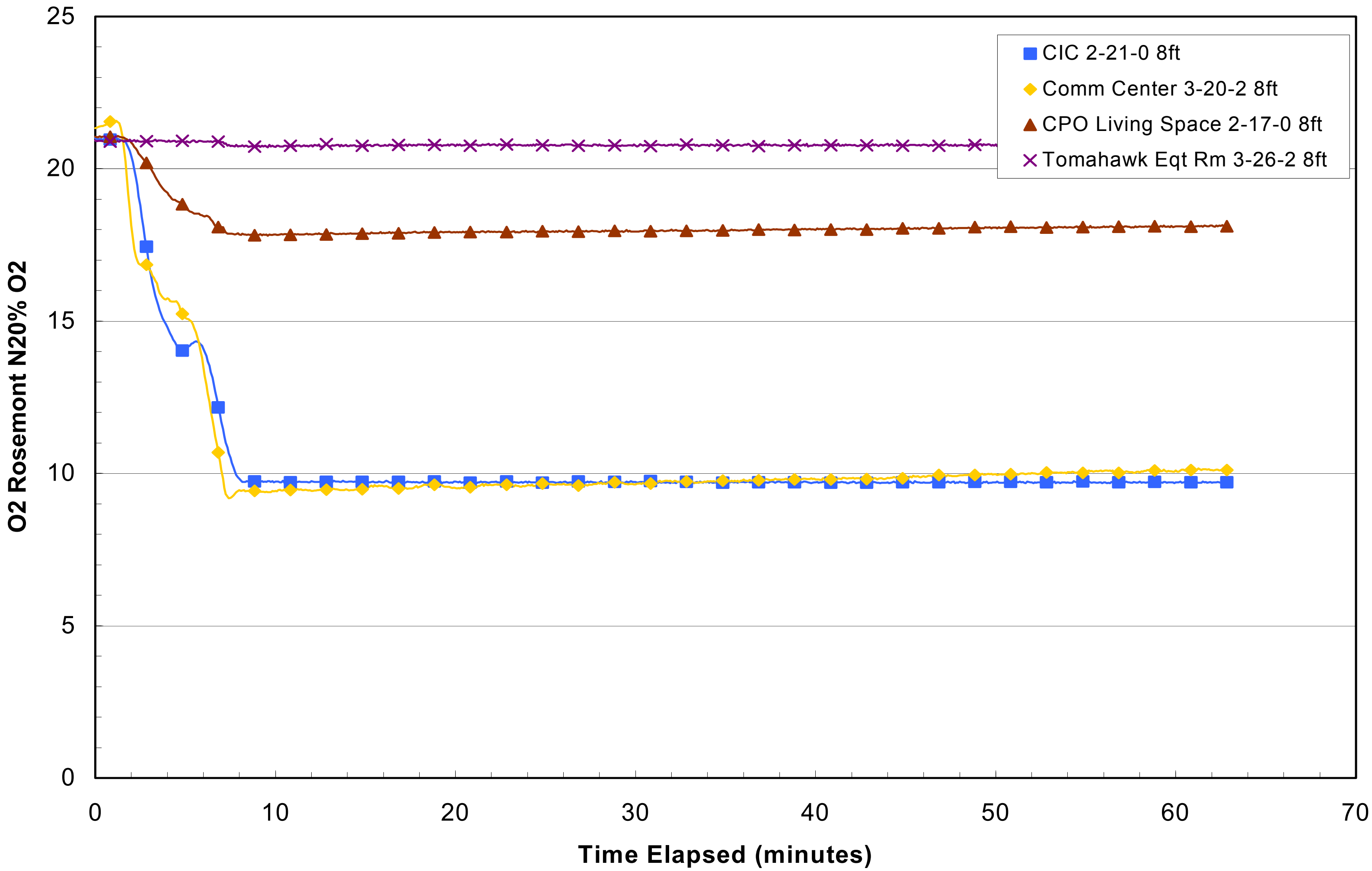


Fig. M1 – Oxygen Concentrations, Demonstration arm3w05

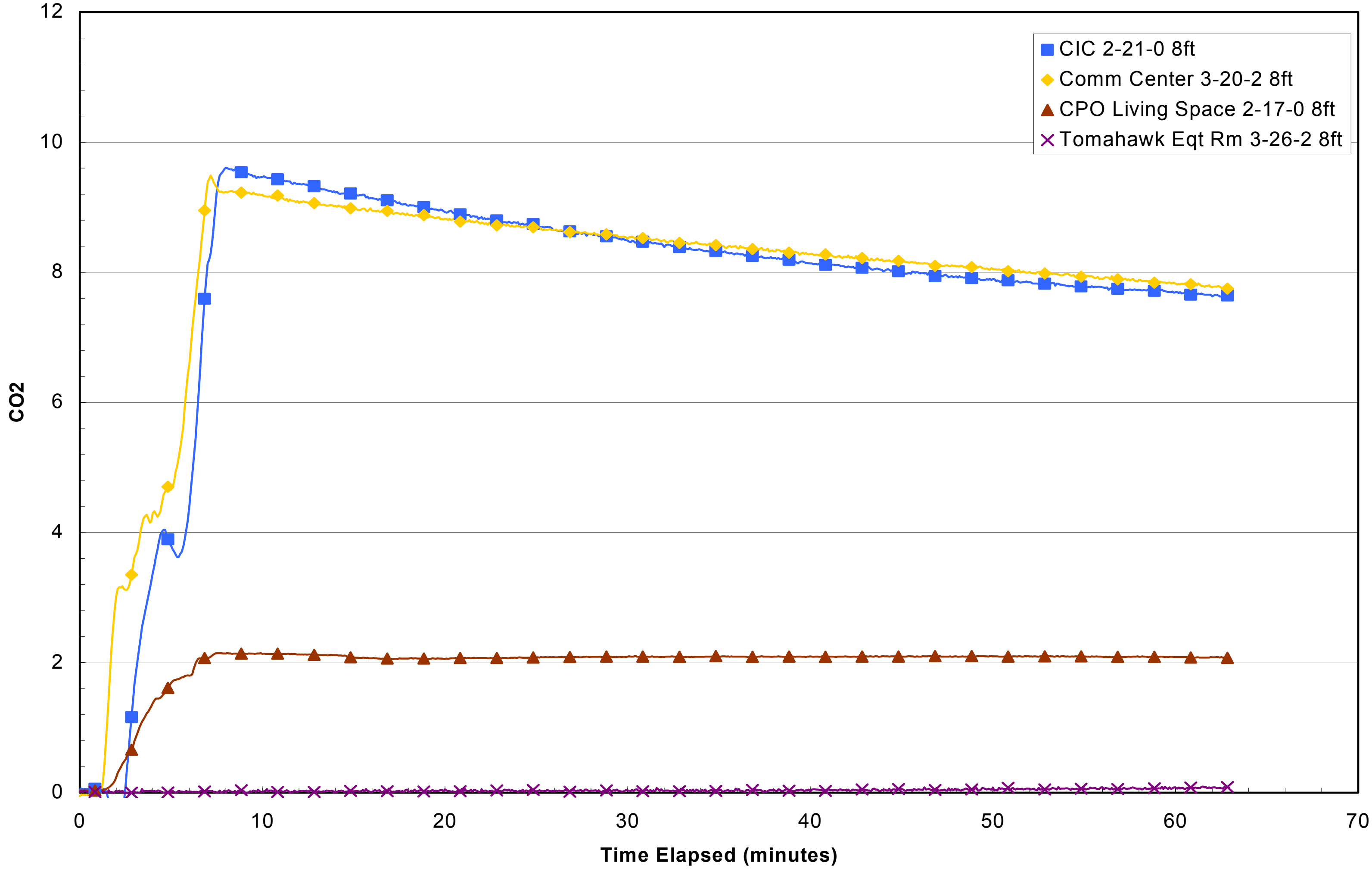


Fig. M2 – Carbon Dioxide Concentrations, Demonstration arm3w05

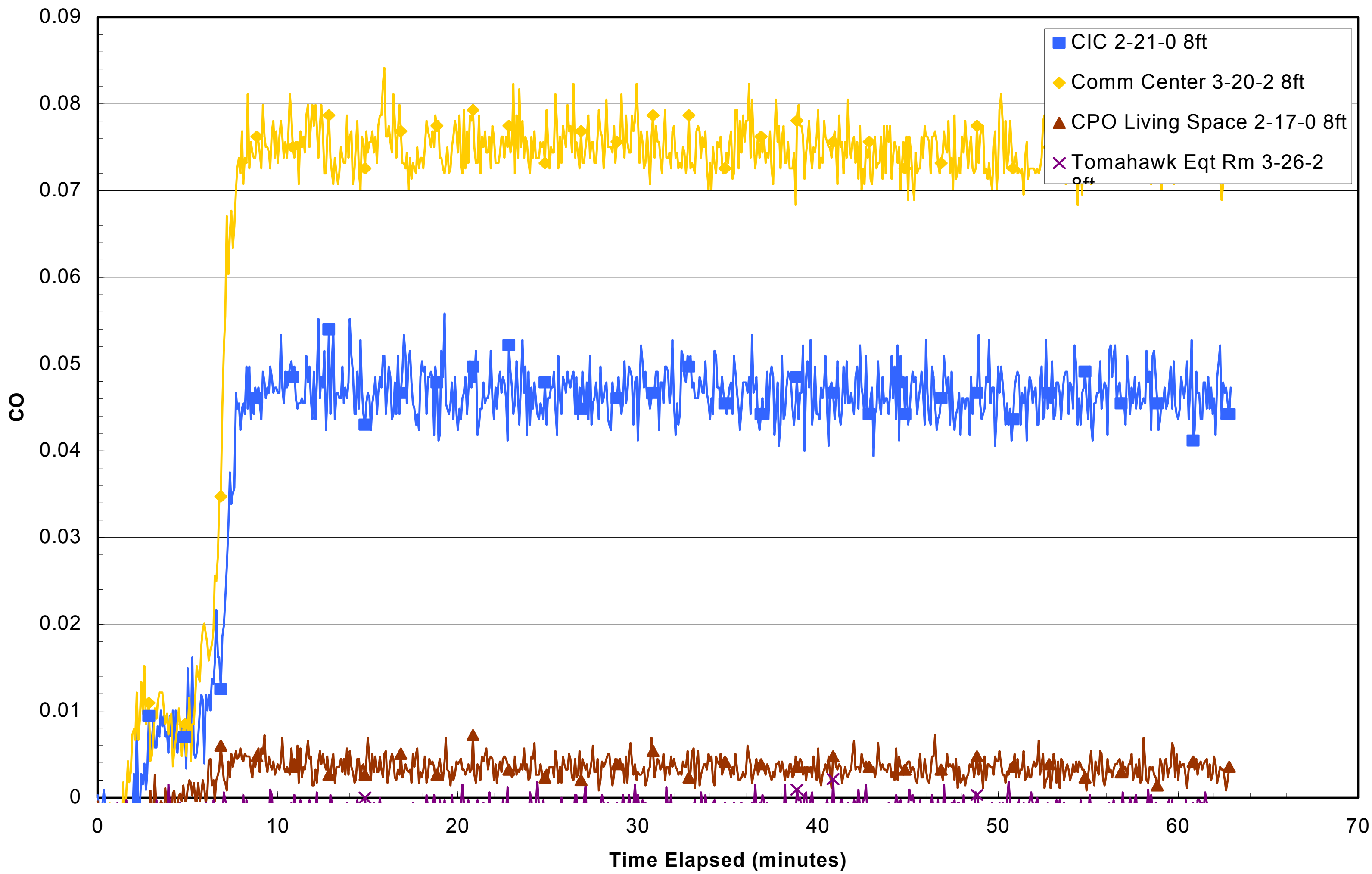


Fig. M3 – Carbon Monoxide Concentrations, Demonstration arm3w05

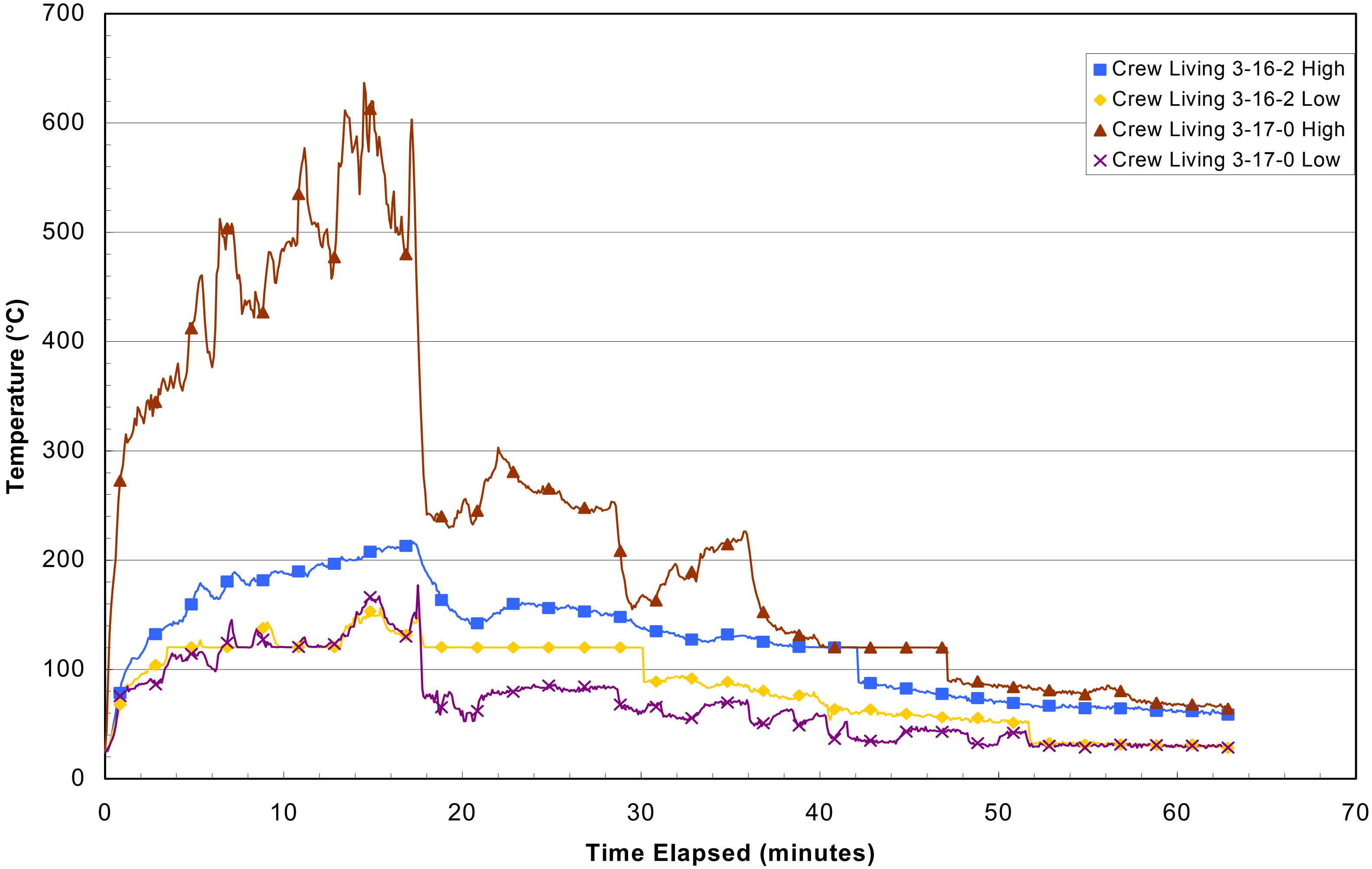


Fig. M4 – Crew Living Temperatures, Demonstration arm3w05

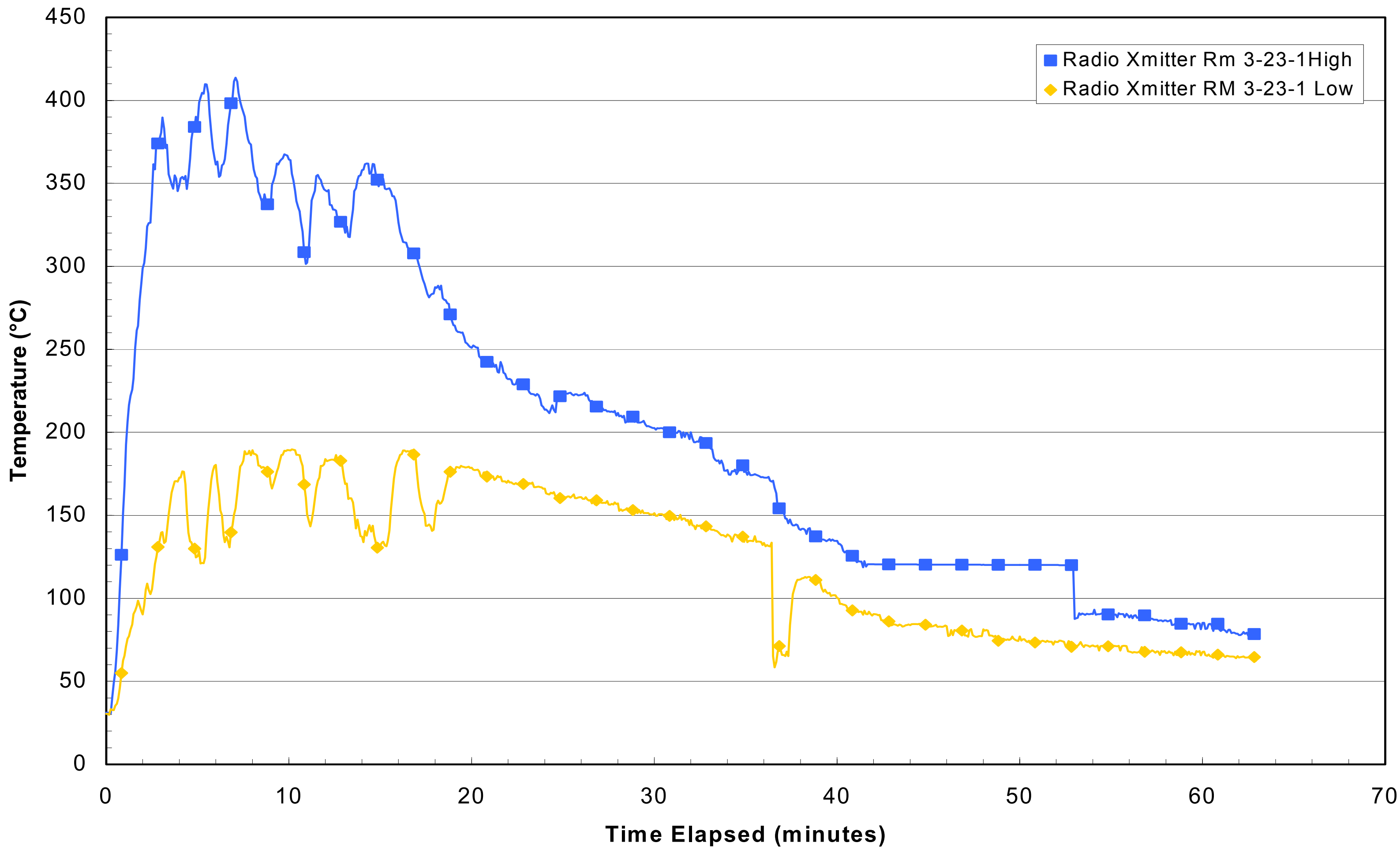


Fig. M5 – Radio Transmitter Room Temperatures, Demonstration arm3w05

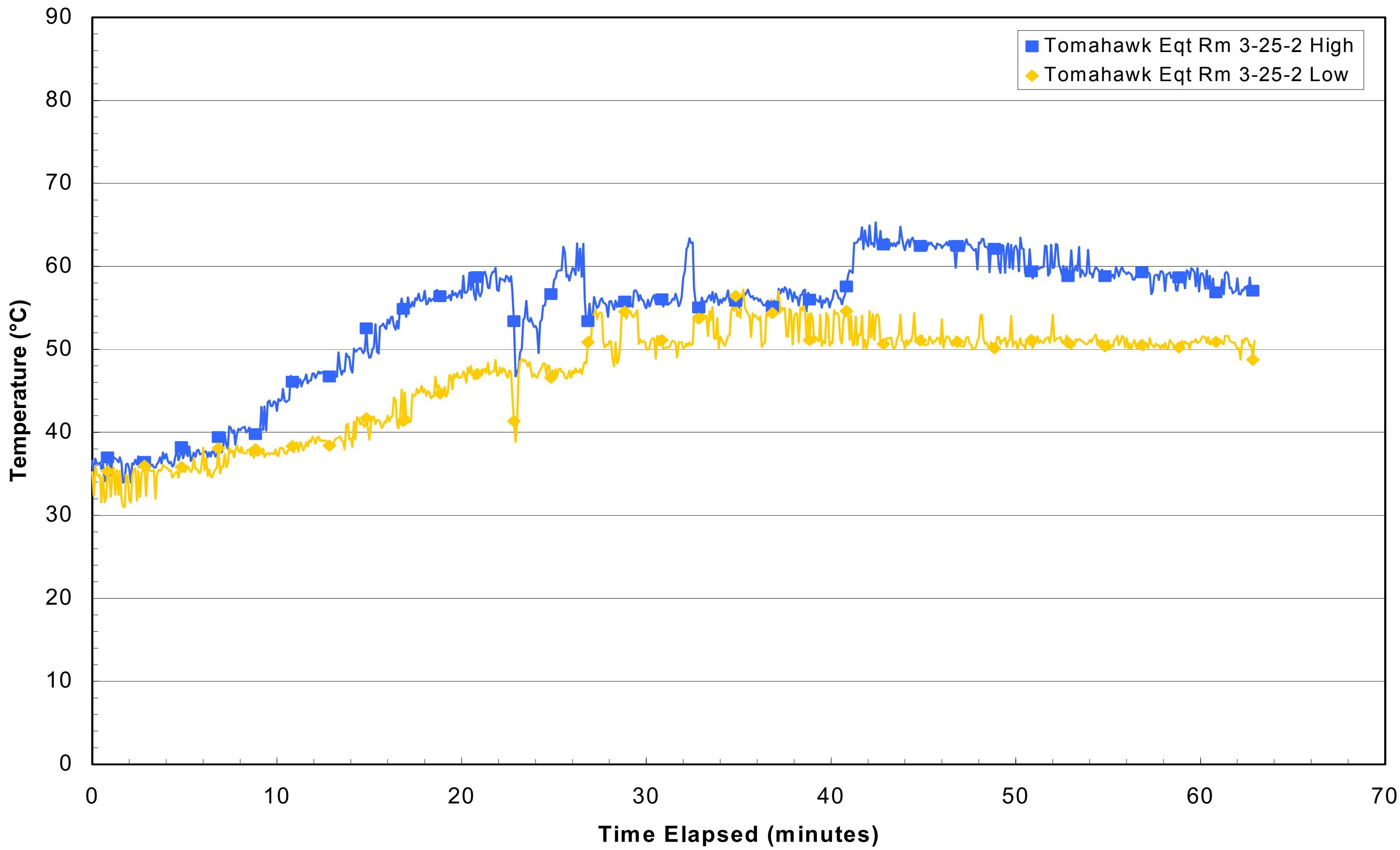


Fig. M6 – Tomahawk Equipment Room Temperatures, Demonstration arm3w05

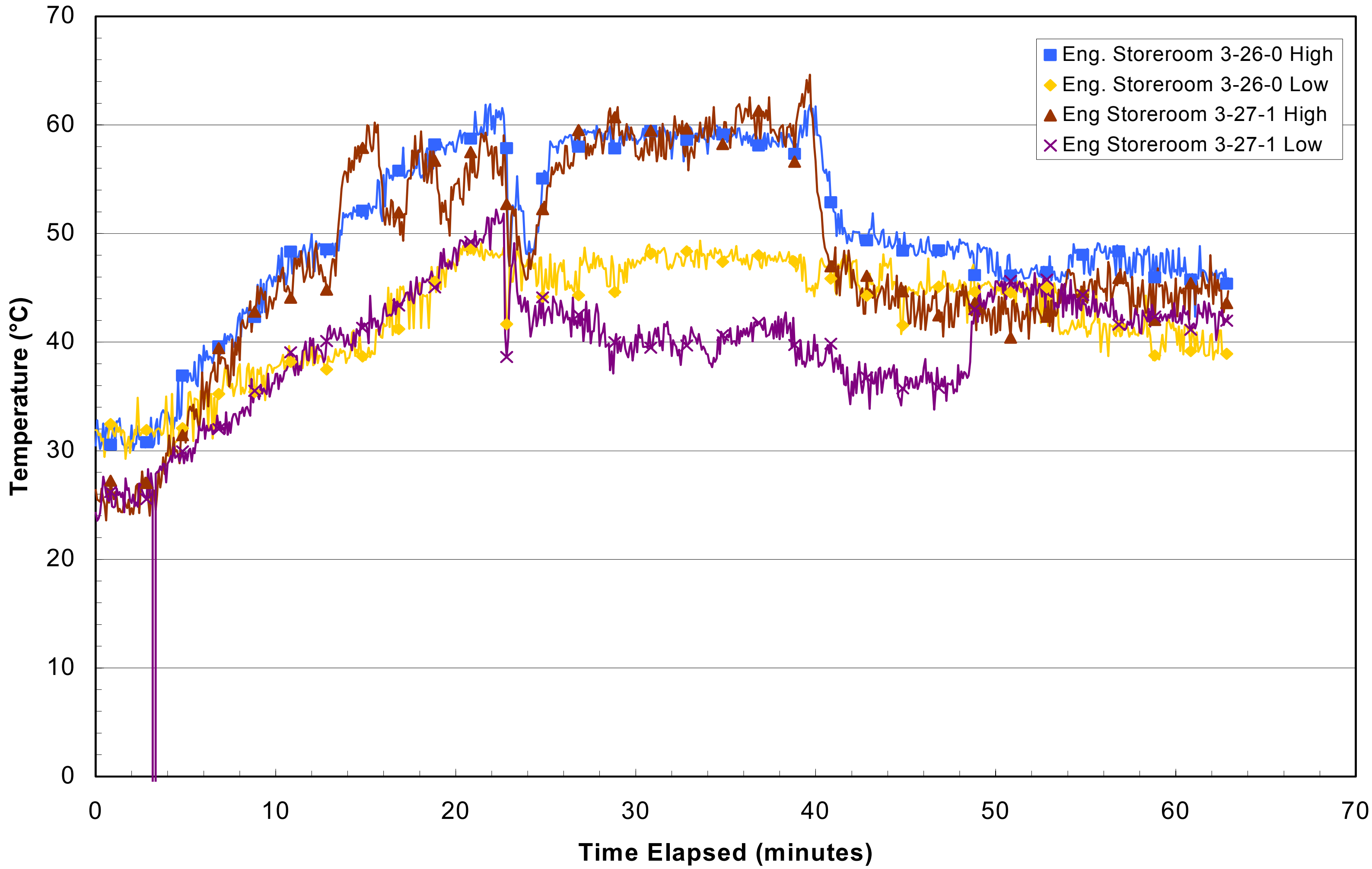


Fig. M7 – Engineering Storeroom Temperatures, Demonstration arm3w05

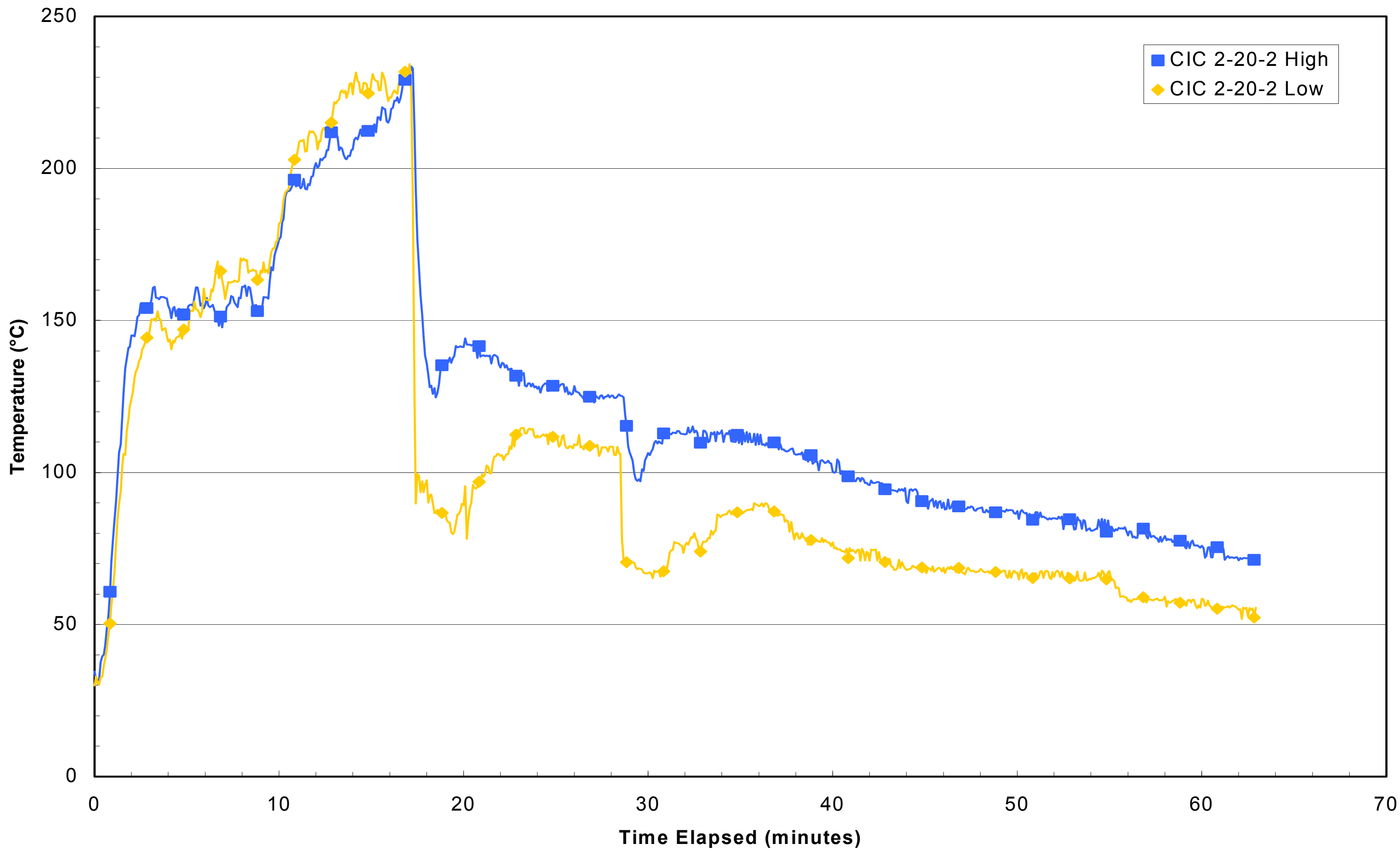


Fig. M8 – CIC Temperatures, Demonstration arm3w05

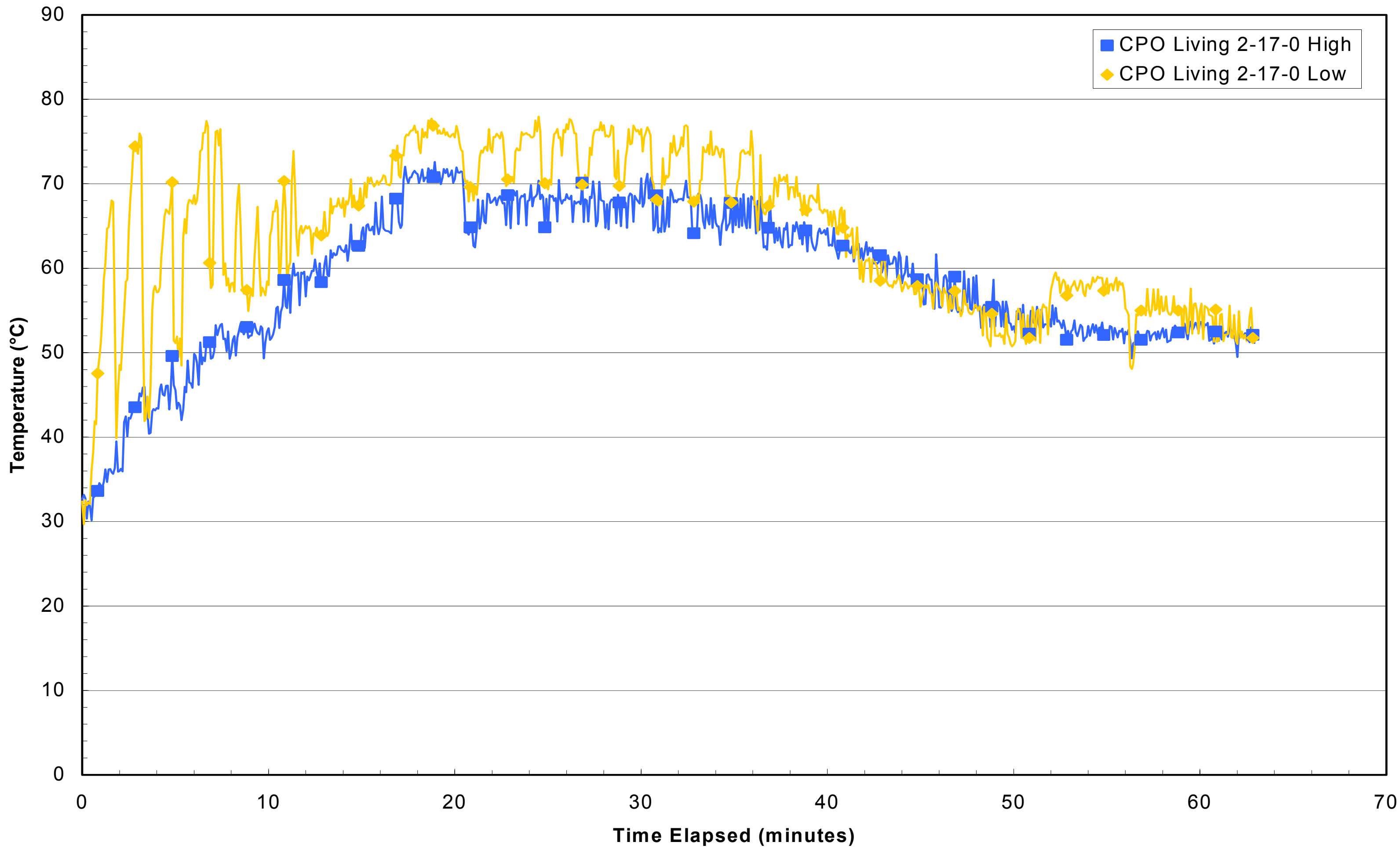


Fig. M9 – CPO Living Temperatures, Demonstration arm3w05

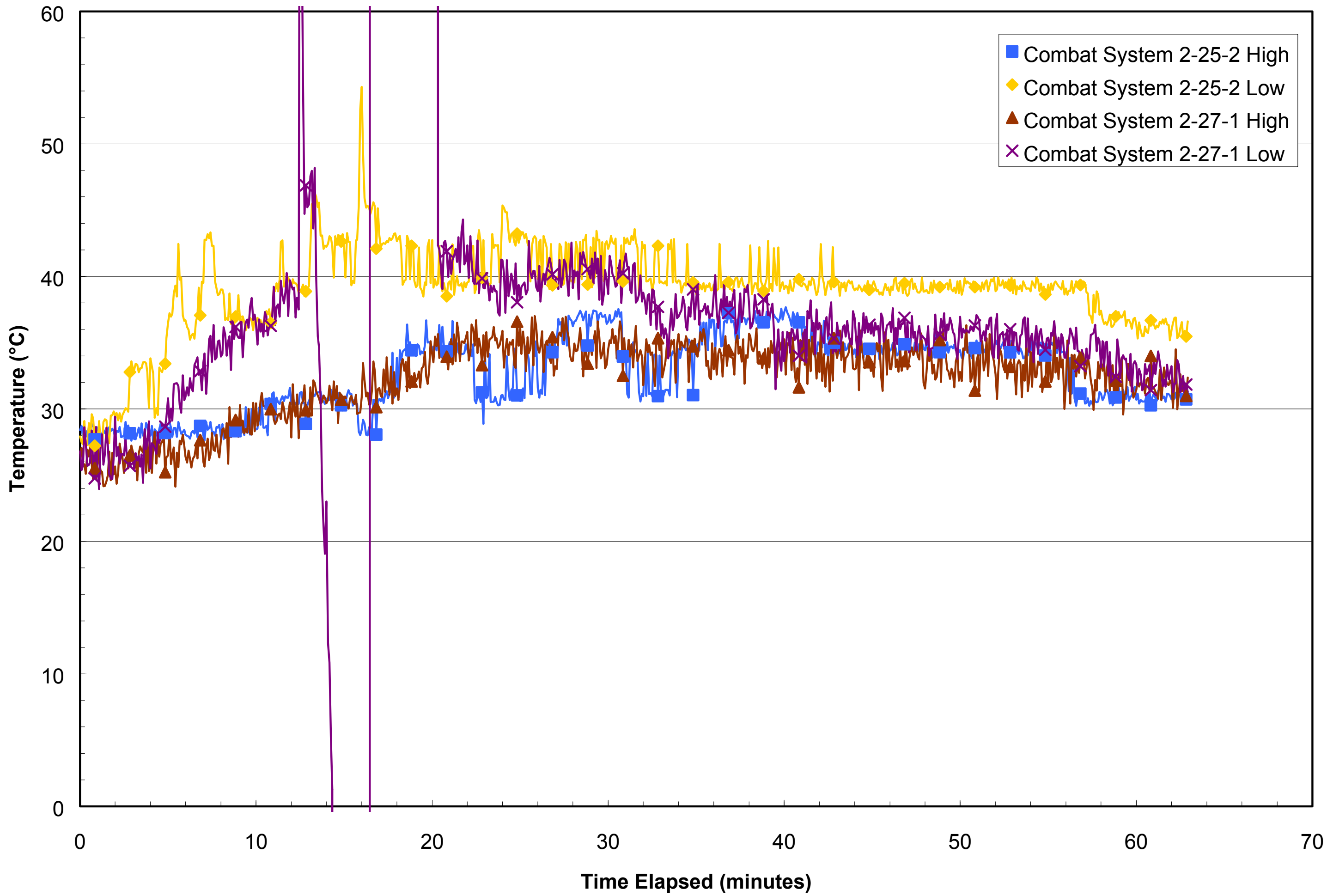


Fig. M10 – Combat Systems Office Temperatures, Demonstration arm3w05

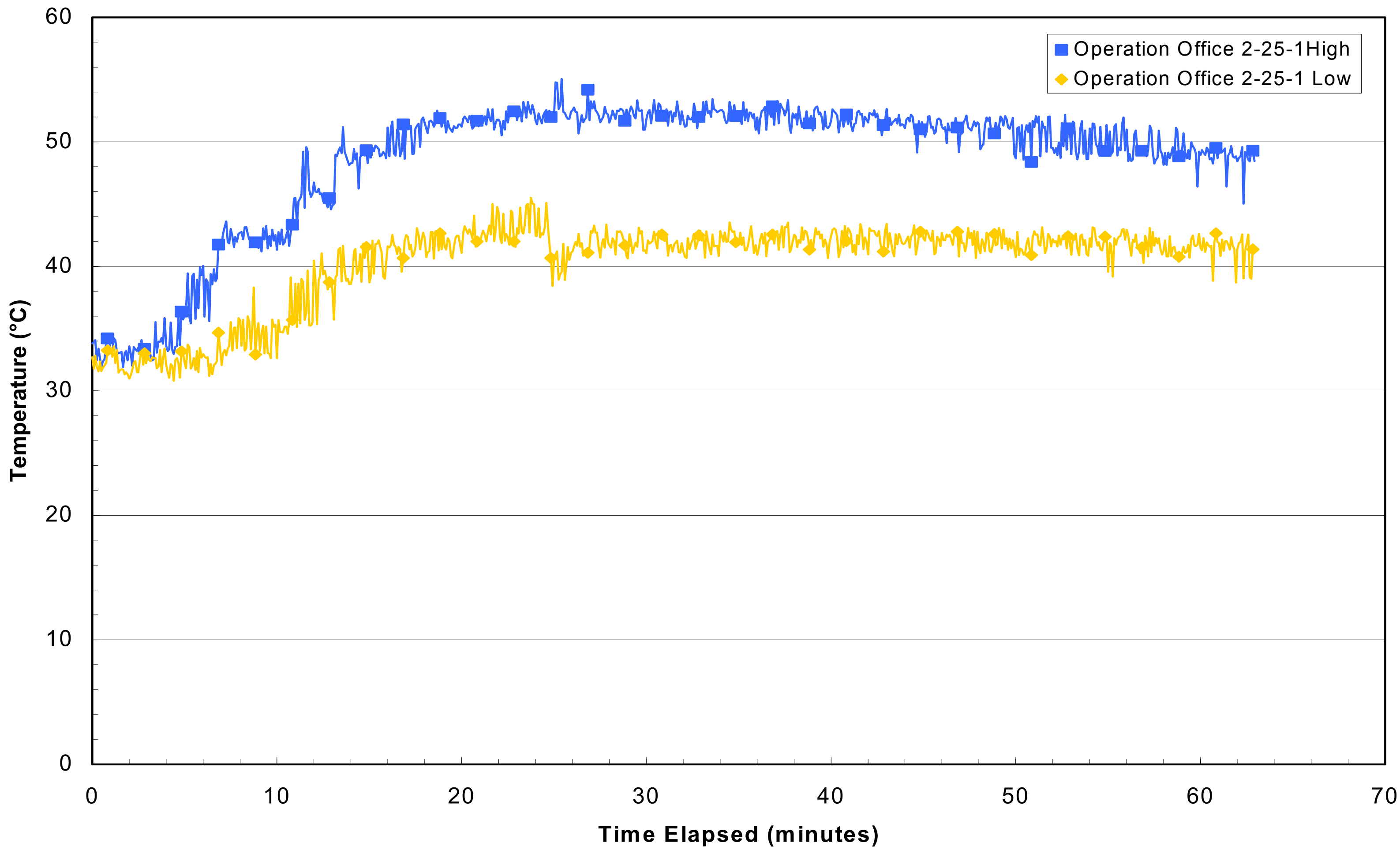


Fig. M11 – Ops Office Temperatures, Demonstration arm3w05

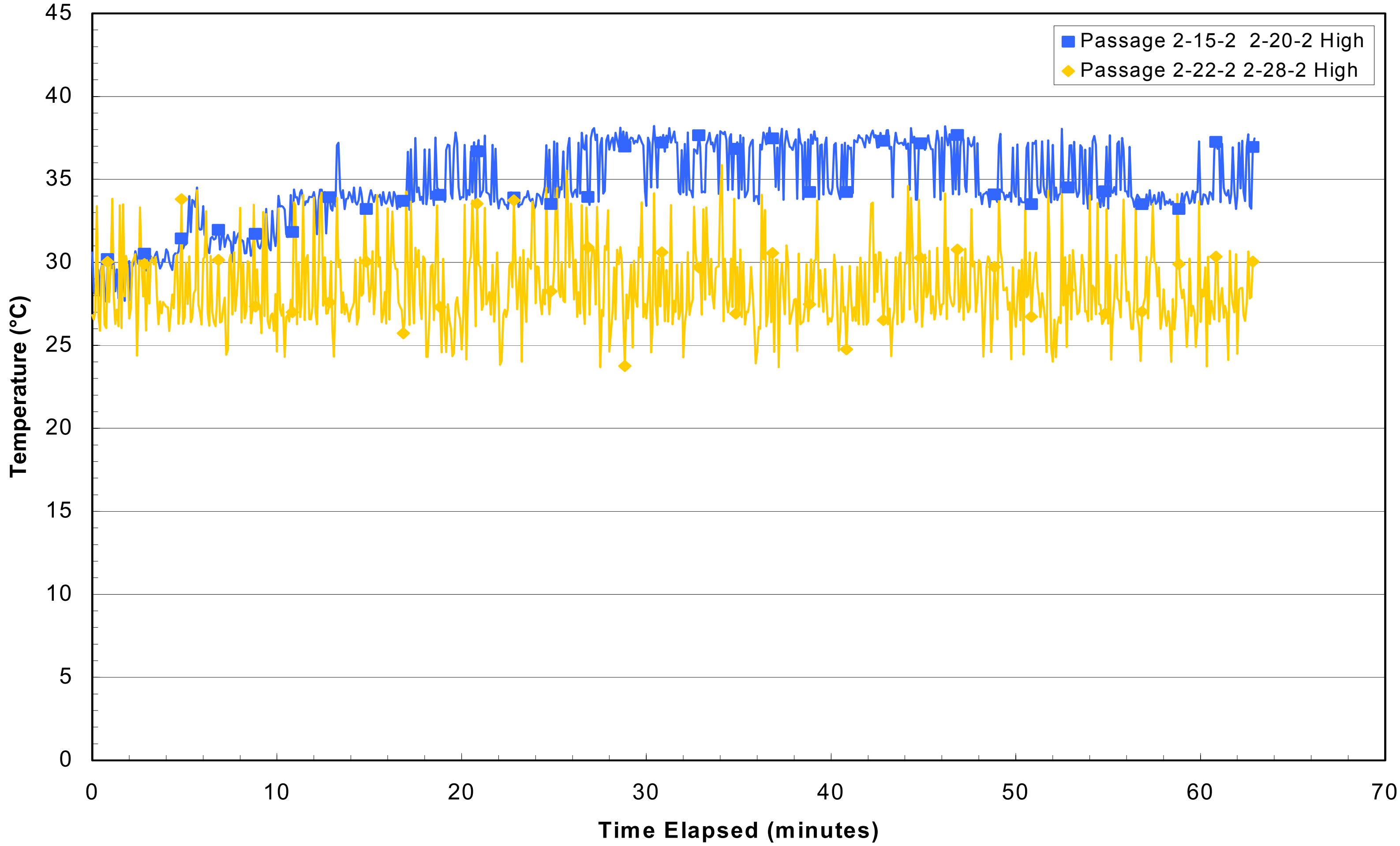


Fig. M12 – Second Deck Port Passageway Temperatures, Demonstration arm3w05

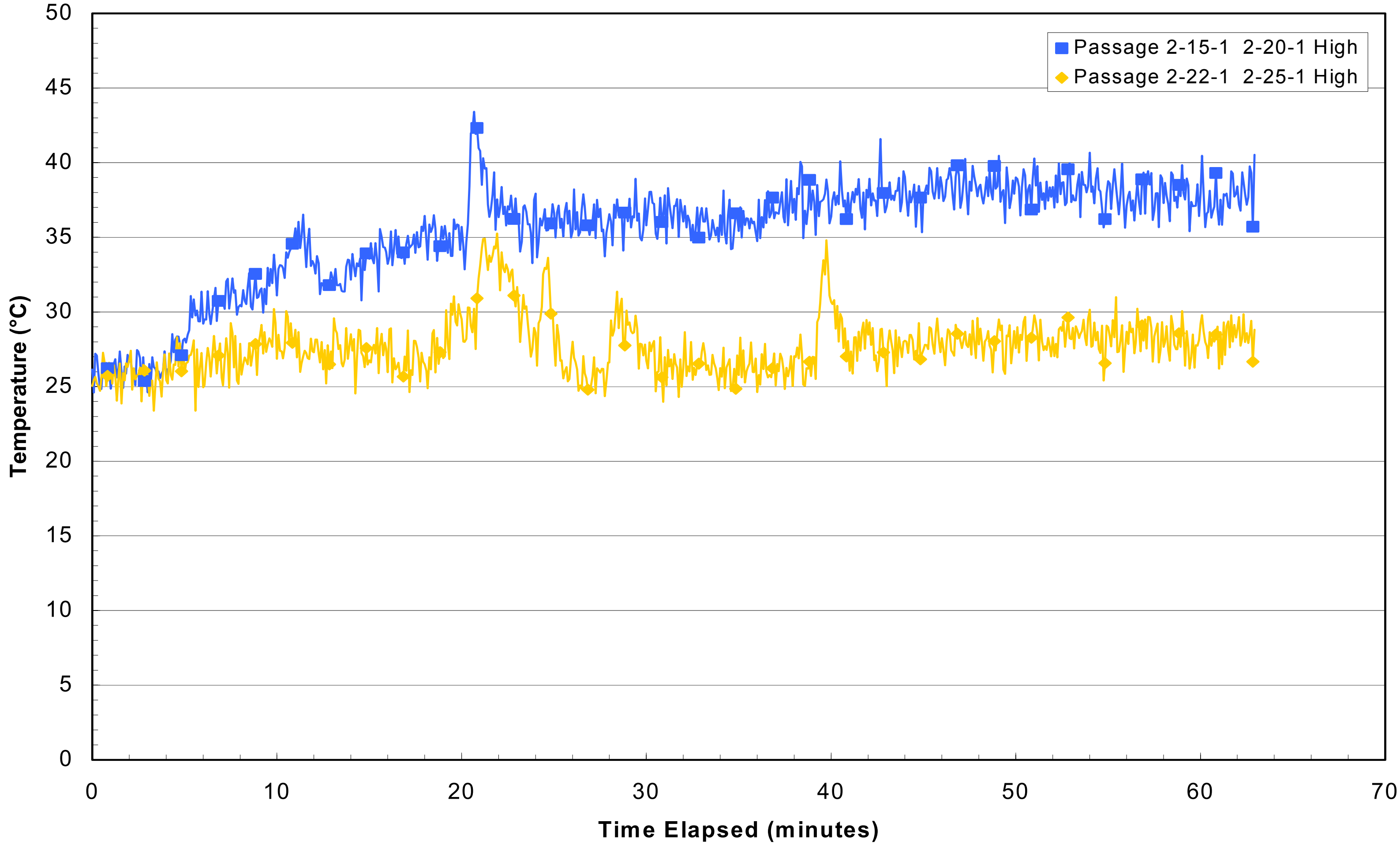


Fig. M13 – Second Deck Starboard Passageway Temperatures, Demonstration arm3w05

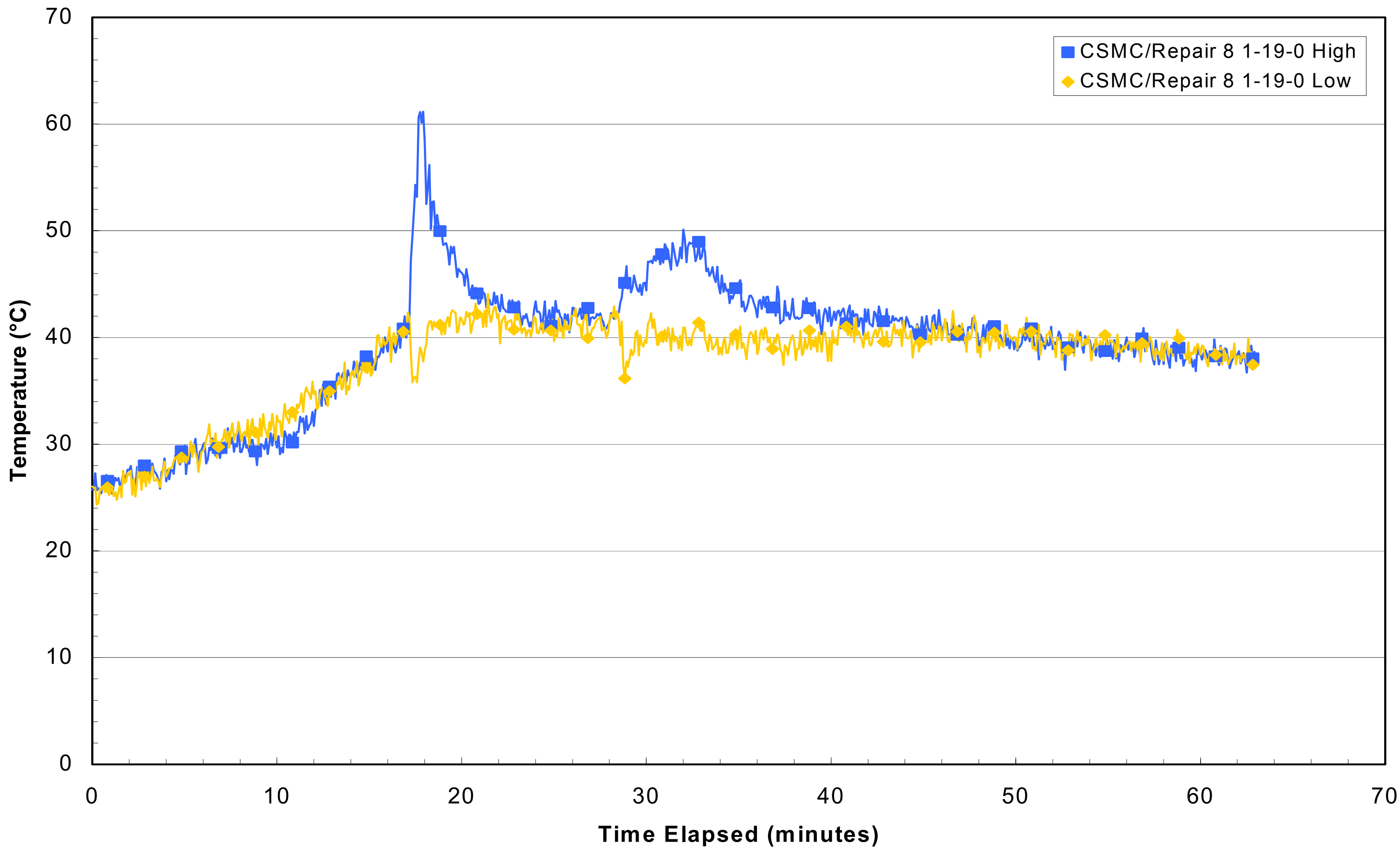


Fig. M14 – CSMC/Repair 8 Temperatures, Demonstration arm3w05

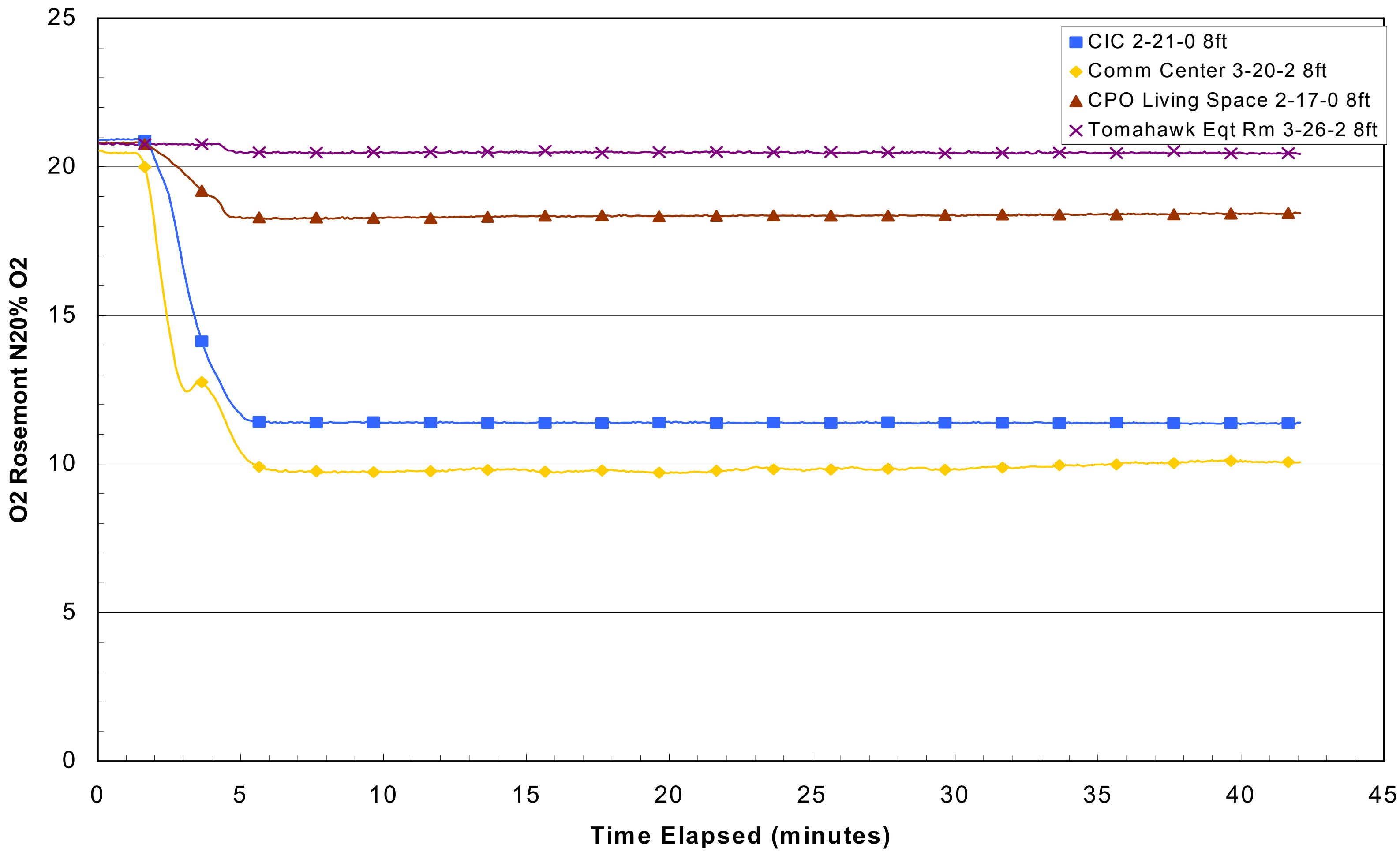


Fig. M15 – Oxygen Concentrations, Demonstration arm3w06

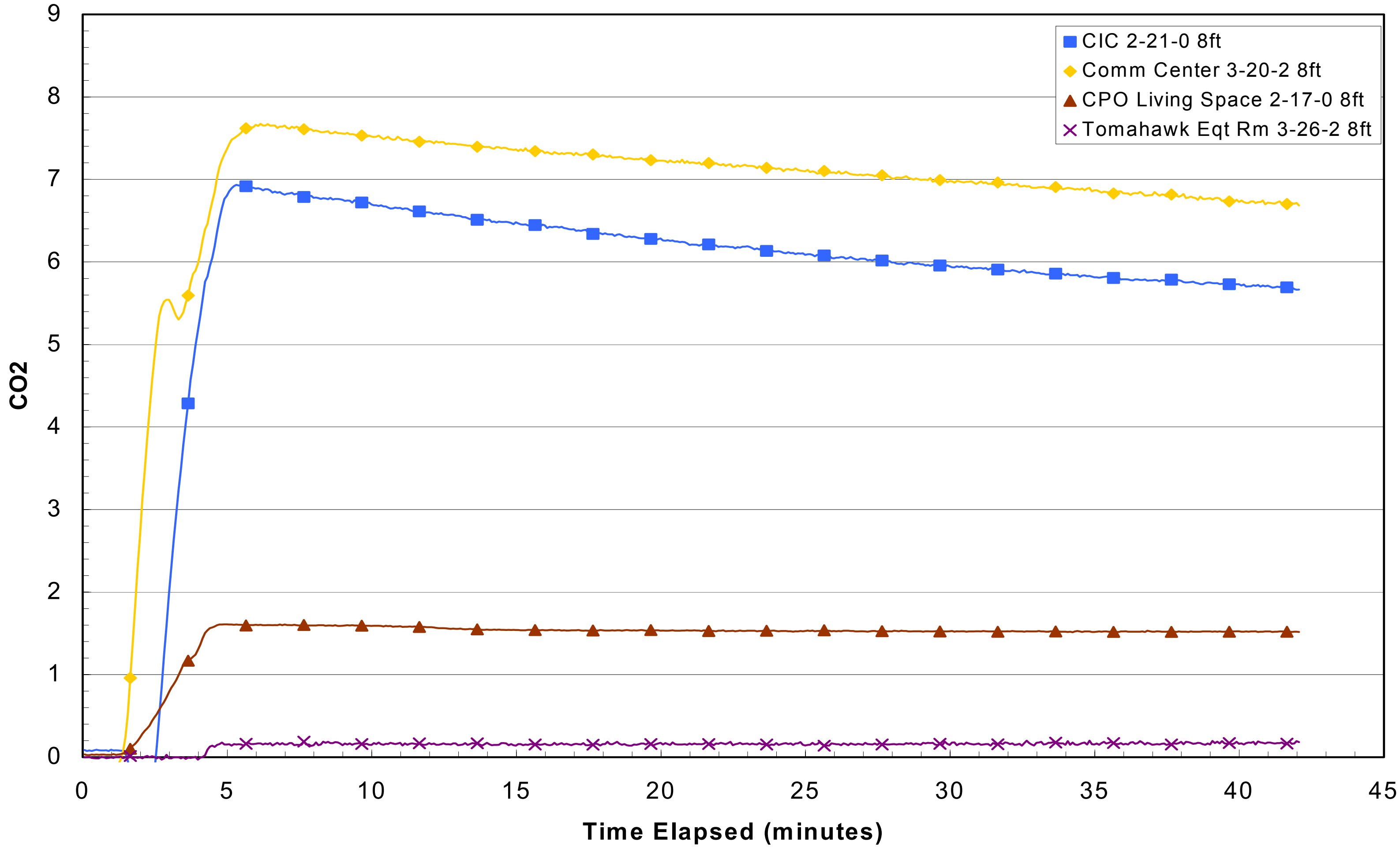


Fig. M16 – Carbon Dioxide Concentrations, Demonstration arm3w06

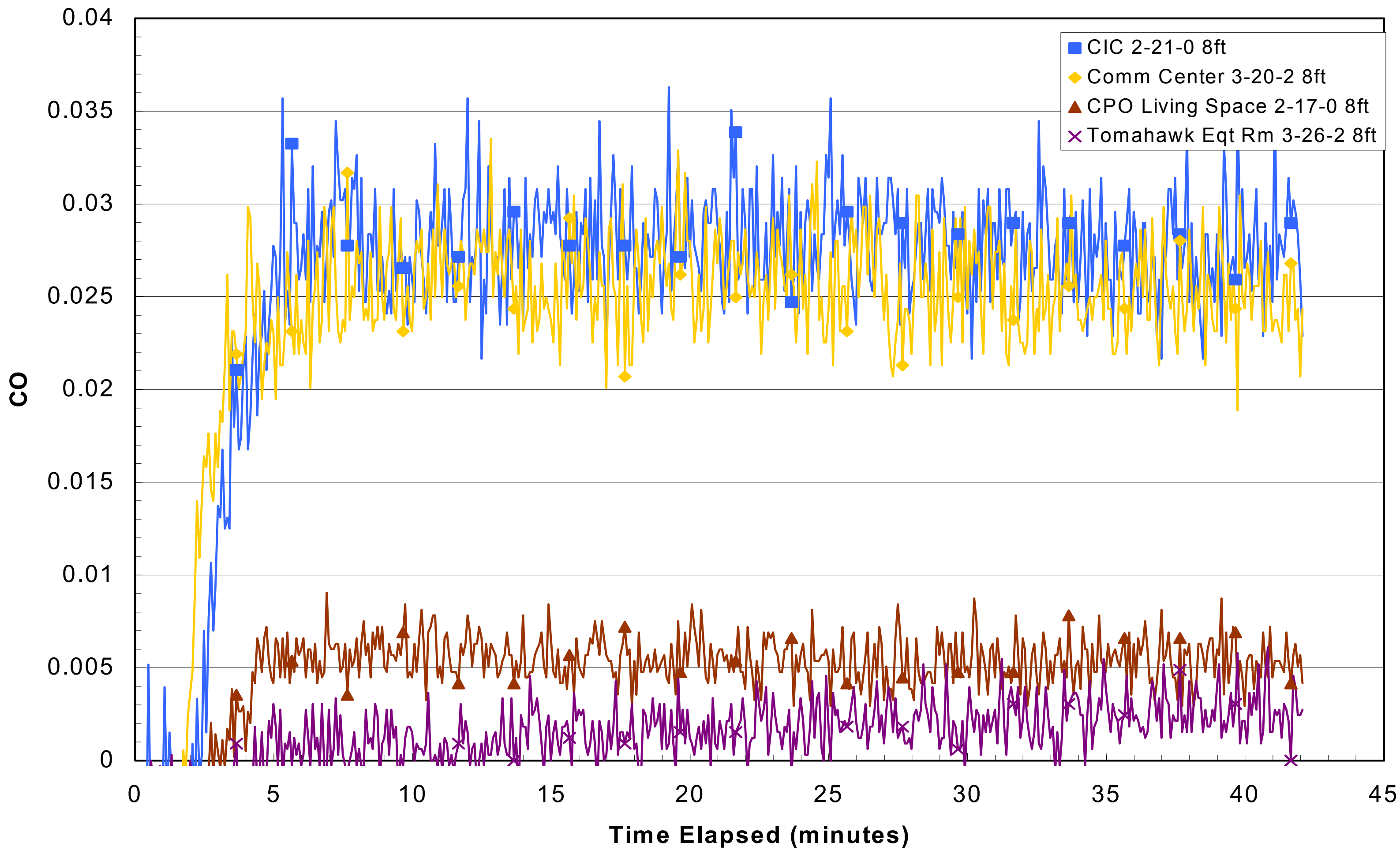


Fig. M17 – Carbon Monoxide Concentrations, Demonstration arm3w06

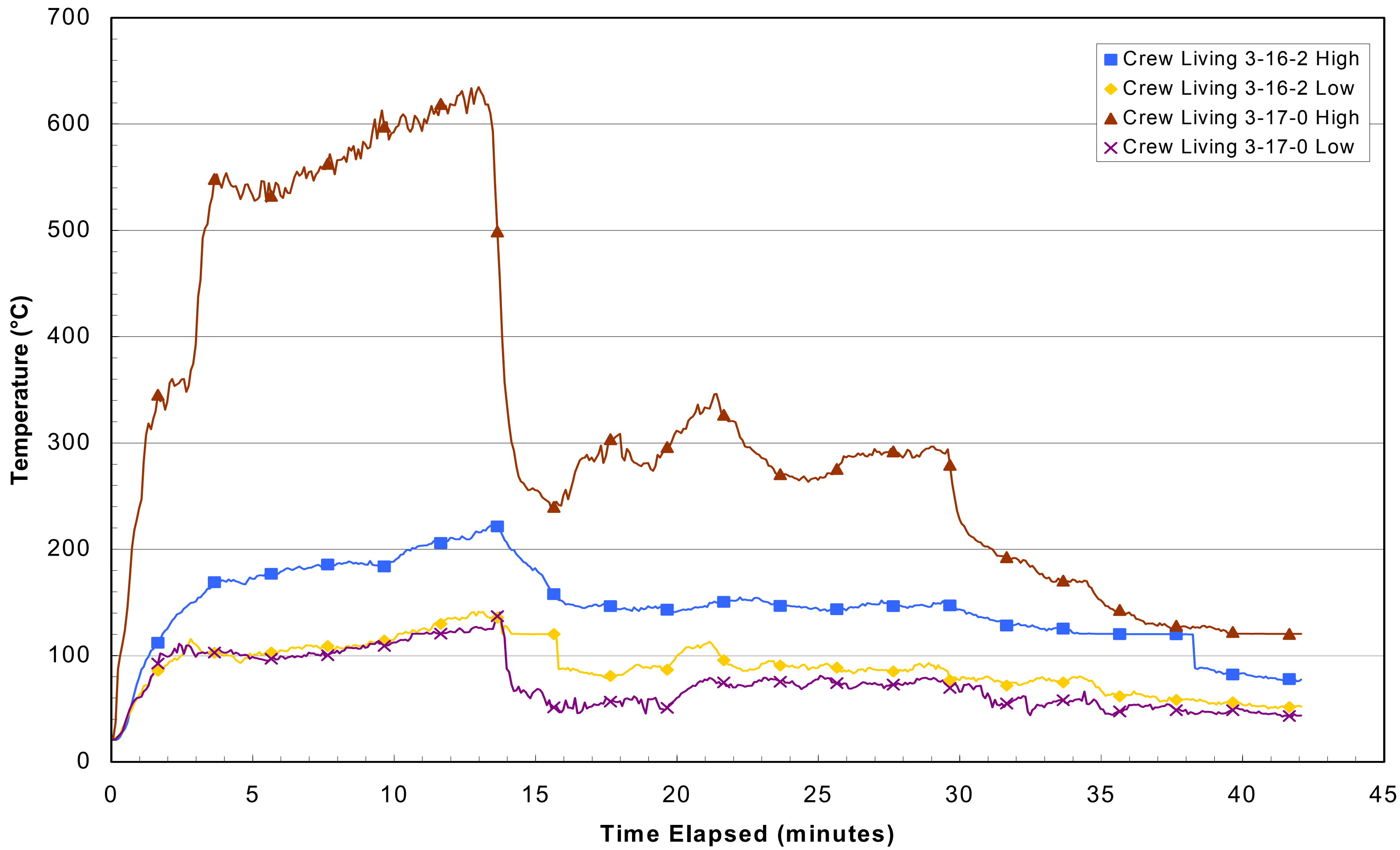


Fig. M18 – Crew Living Temperatures, Demonstration arm3w06

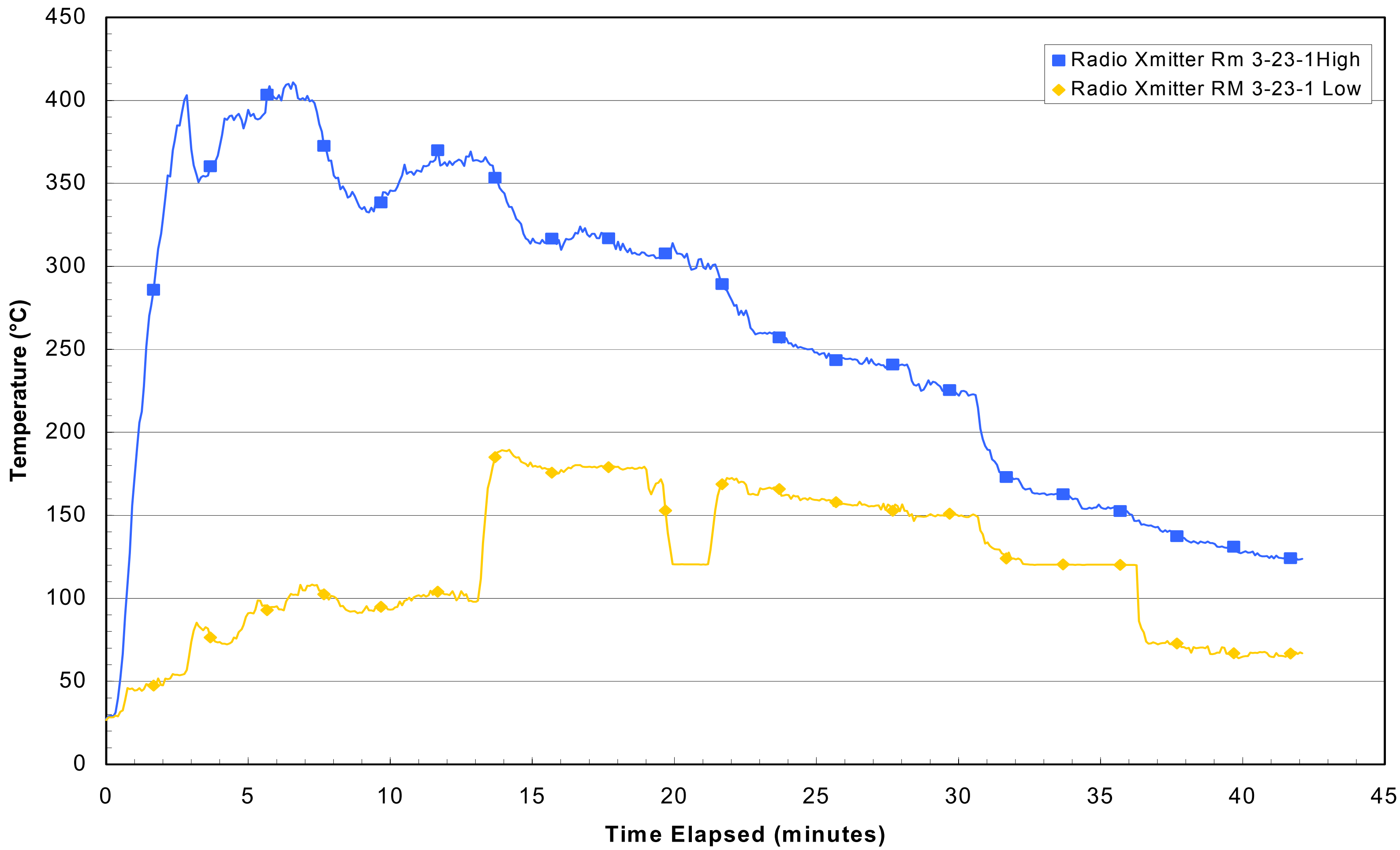


Fig. M19 – Radio Transmitter Room Temperatures, Demonstration arm3w06

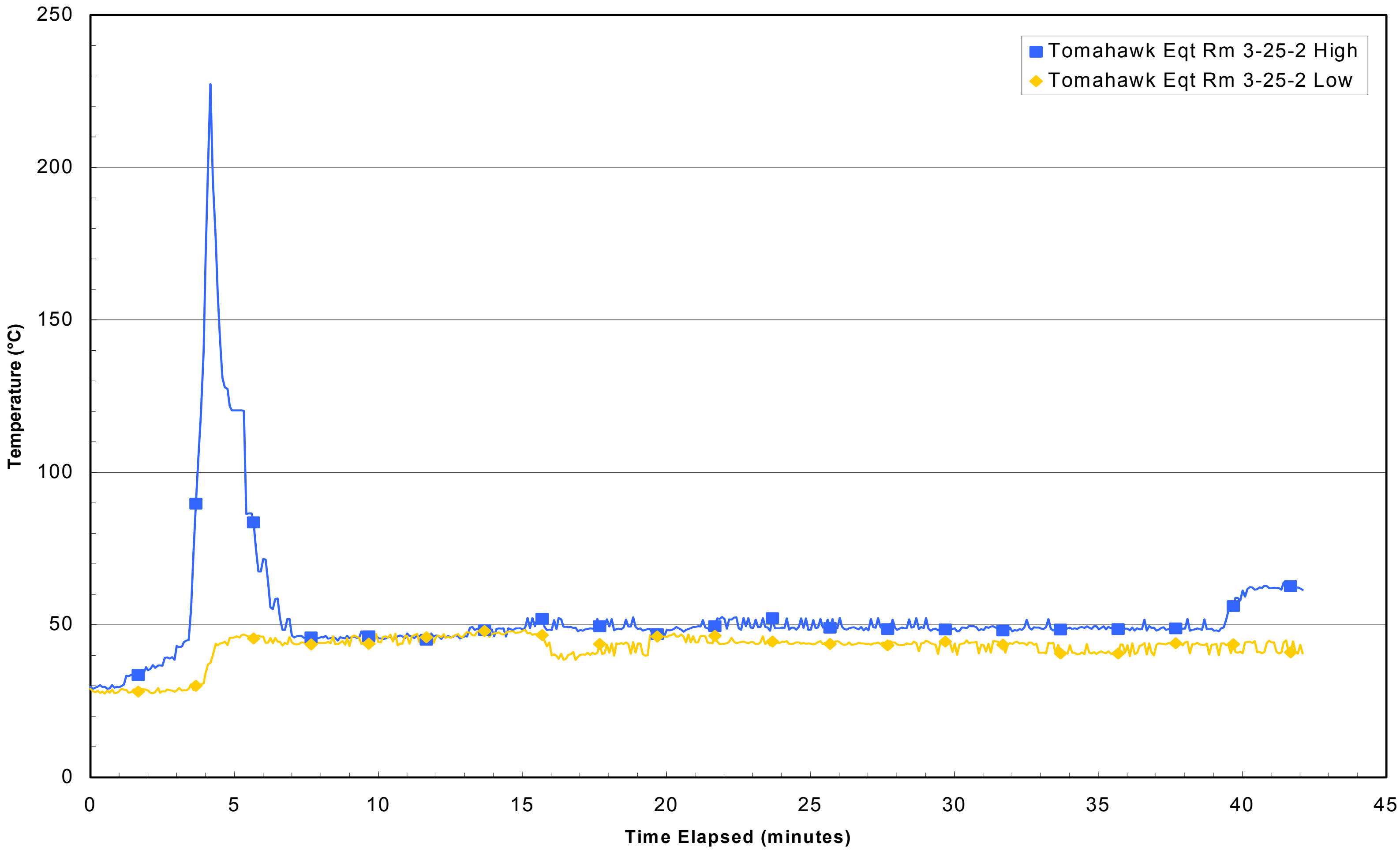


Fig. M20 – Tomahawk Equipment Room Temperatures, Demonstration arm3w06

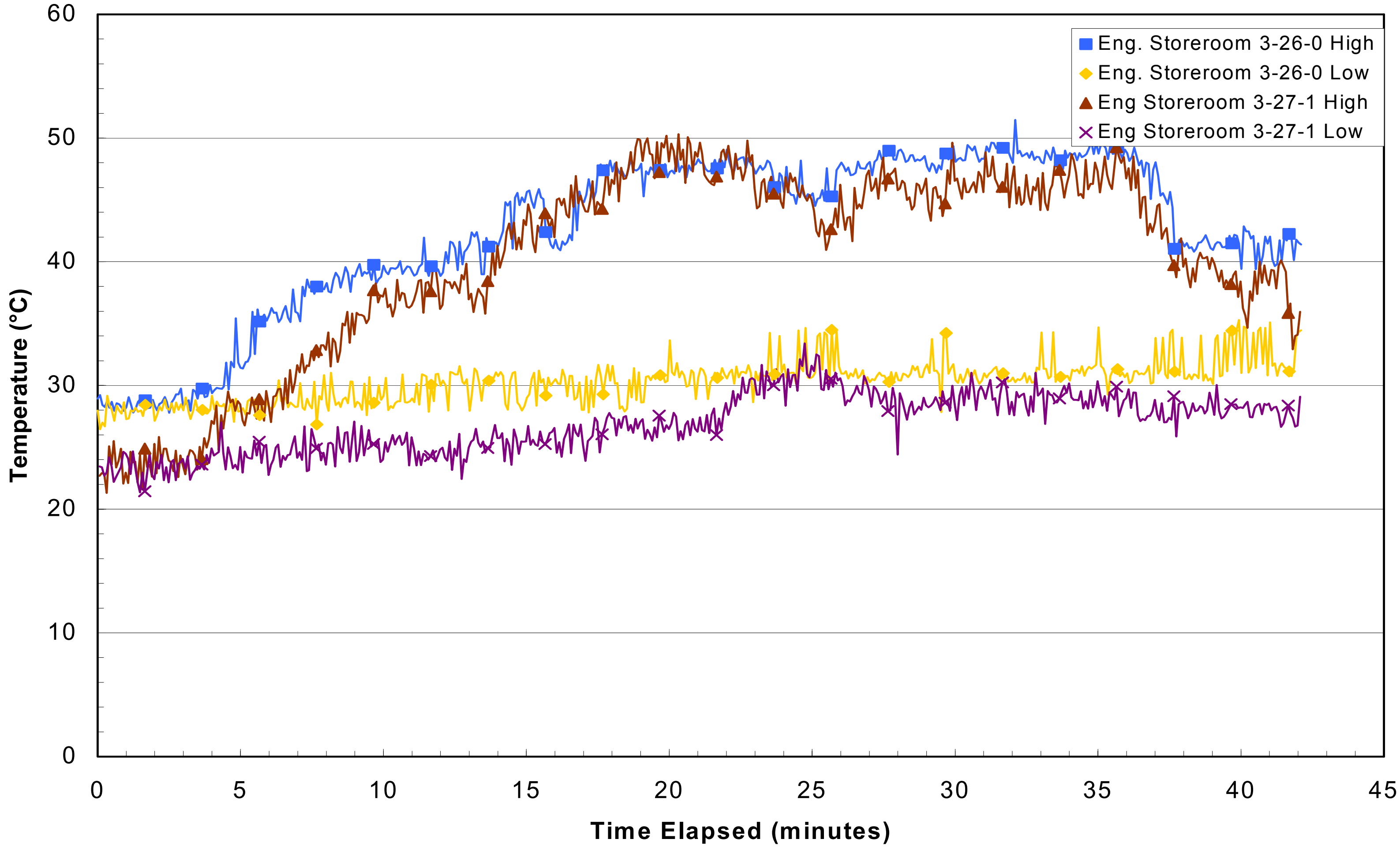


Fig. M21 – Engineering Storeroom Temperatures, Demonstration arm3w06

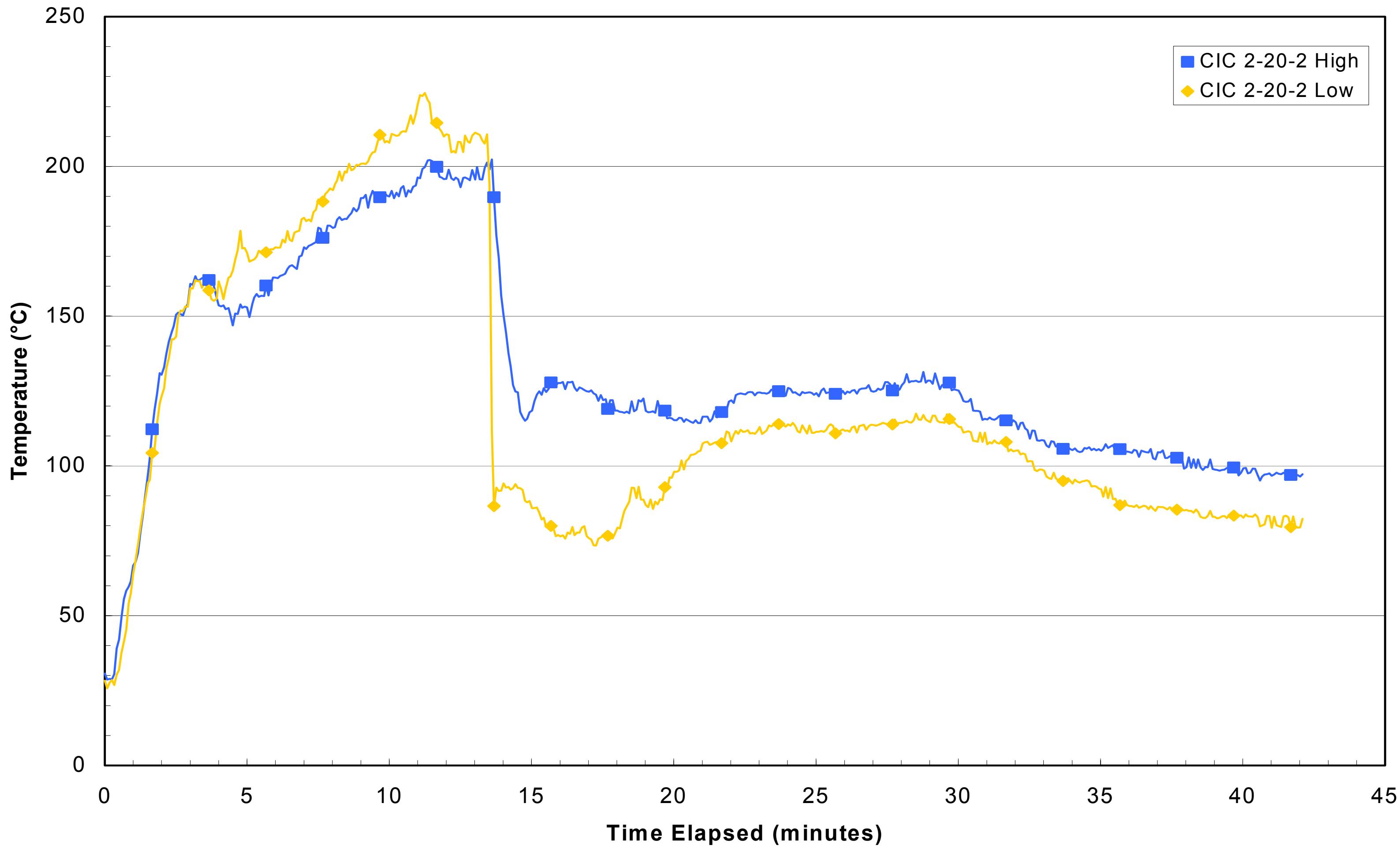


Fig. M22 – CIC Temperatures, Demonstration arm3w06

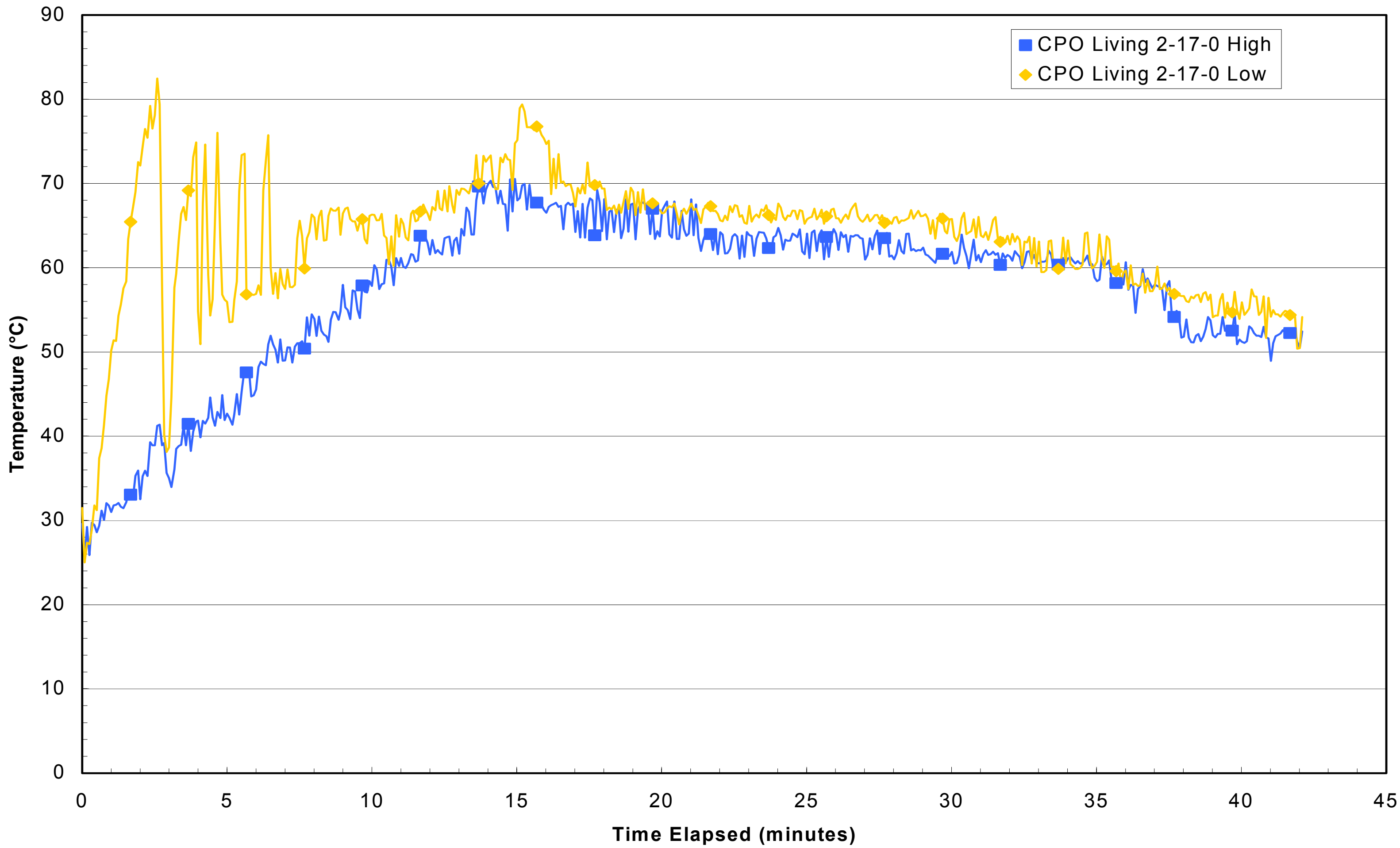


Fig. M23 – CPO Living Temperatures, Demonstration arm3w06

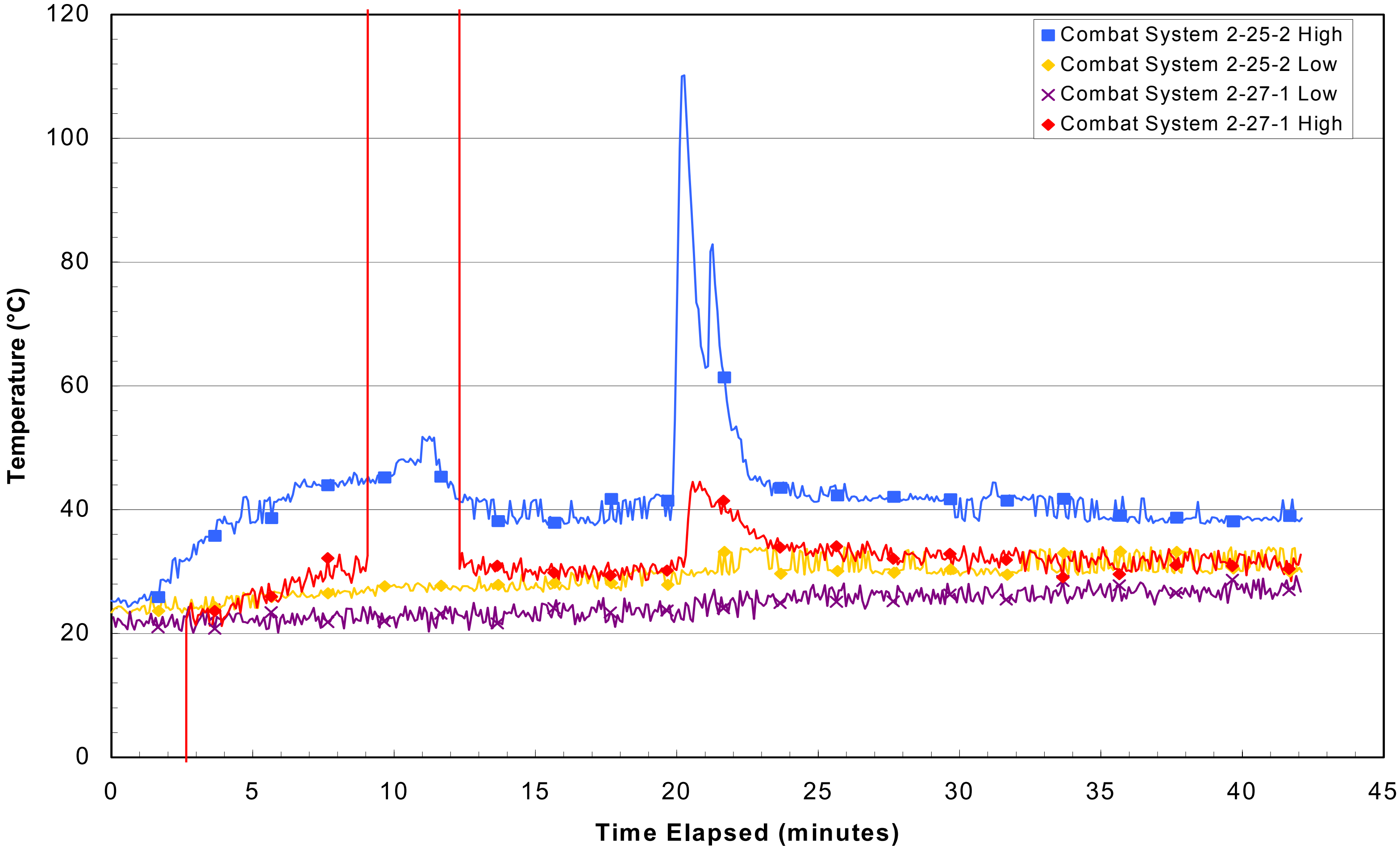


Fig. M24 – Combat Systems Office Temperatures, Demonstration arm3w06

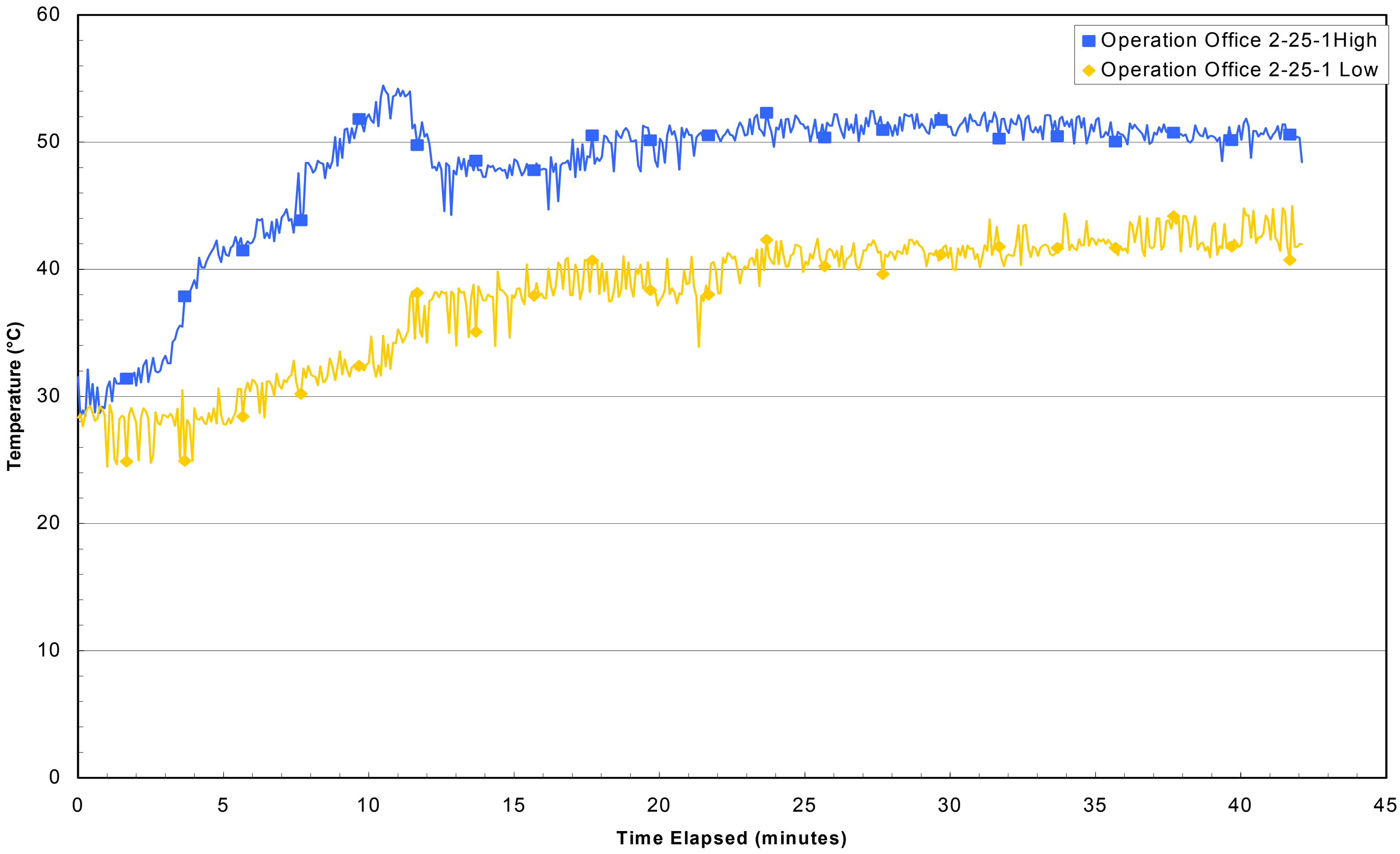


Fig. M25 – Ops Office Temperatures, Demonstration arm3w06

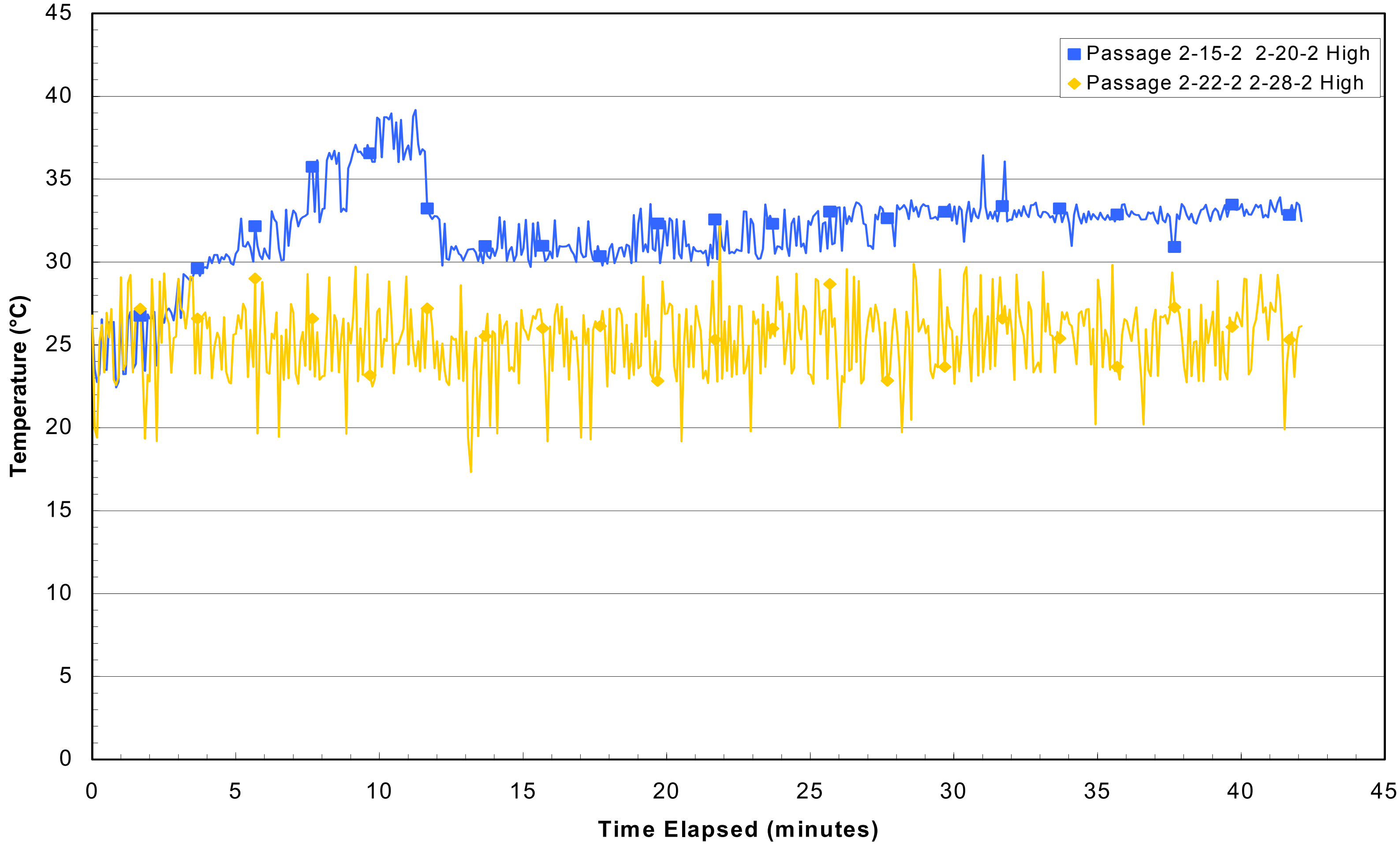


Fig. M26 – Second Deck Port Passageway Temperatures, Demonstration arm3w06

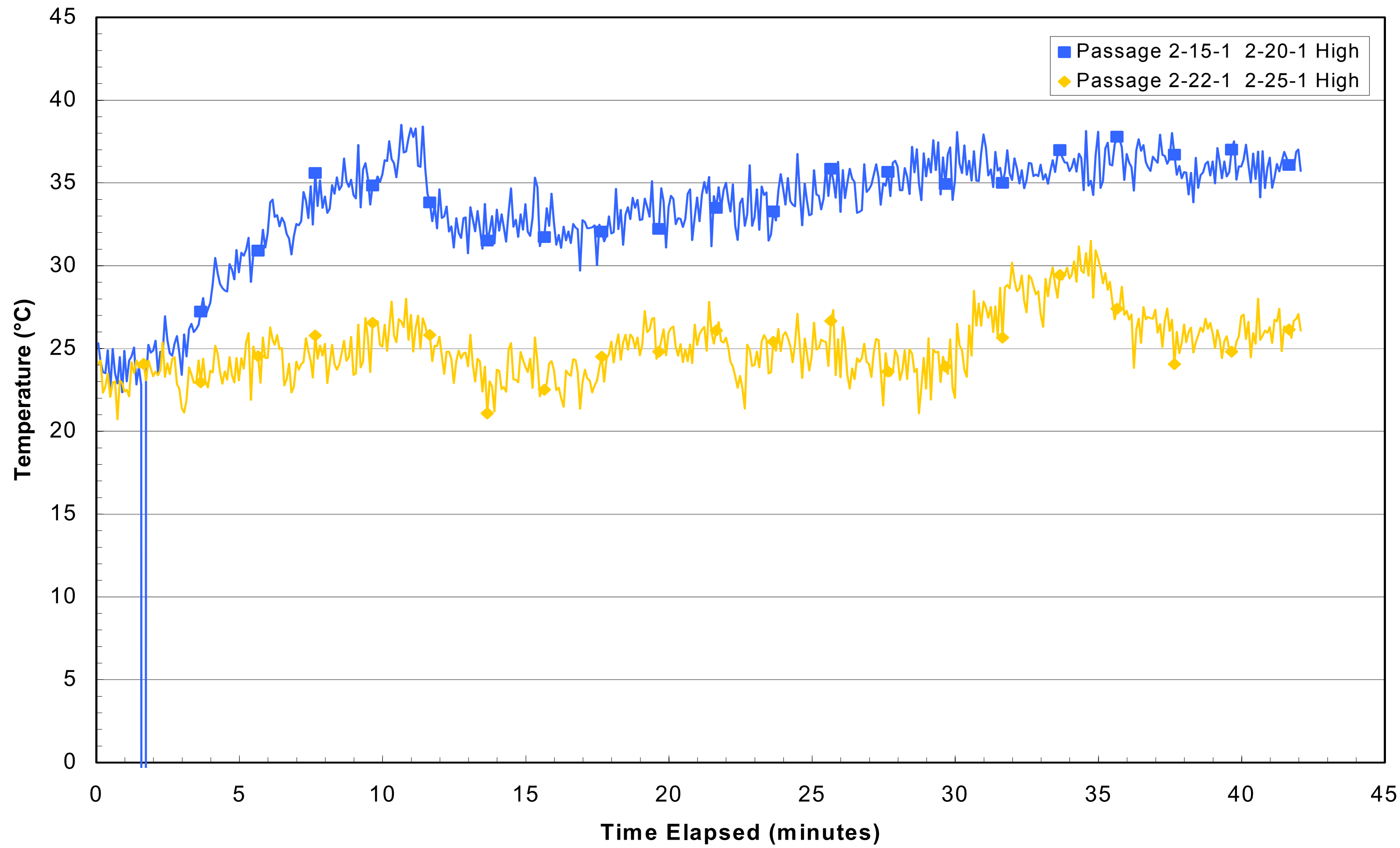


Fig. M27 – Second Deck Starboard Passageway Temperatures, Demonstration arm3w06

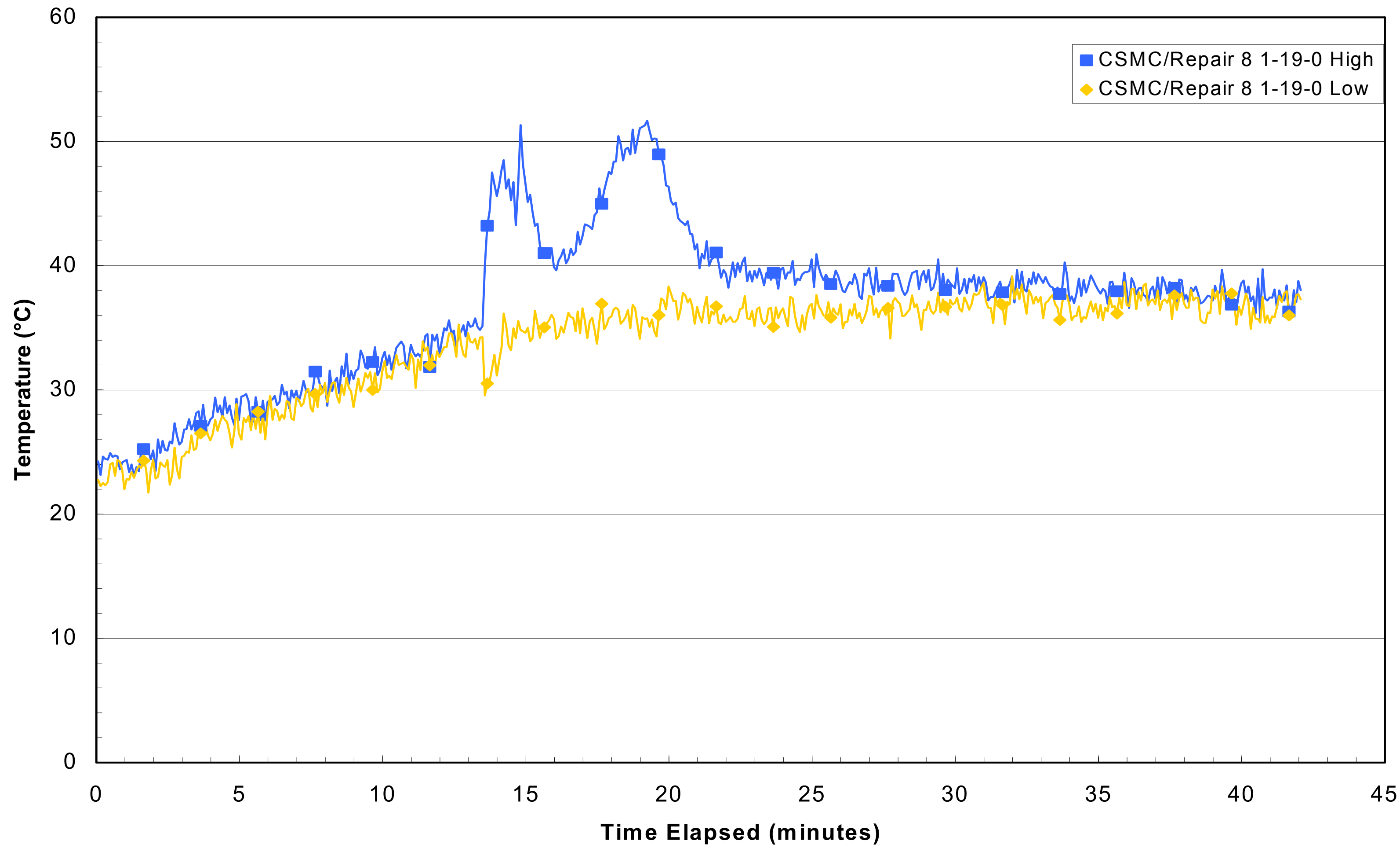


Fig. M28 – CSMC/Repair 8 Temperatures, Demonstration arm3w06

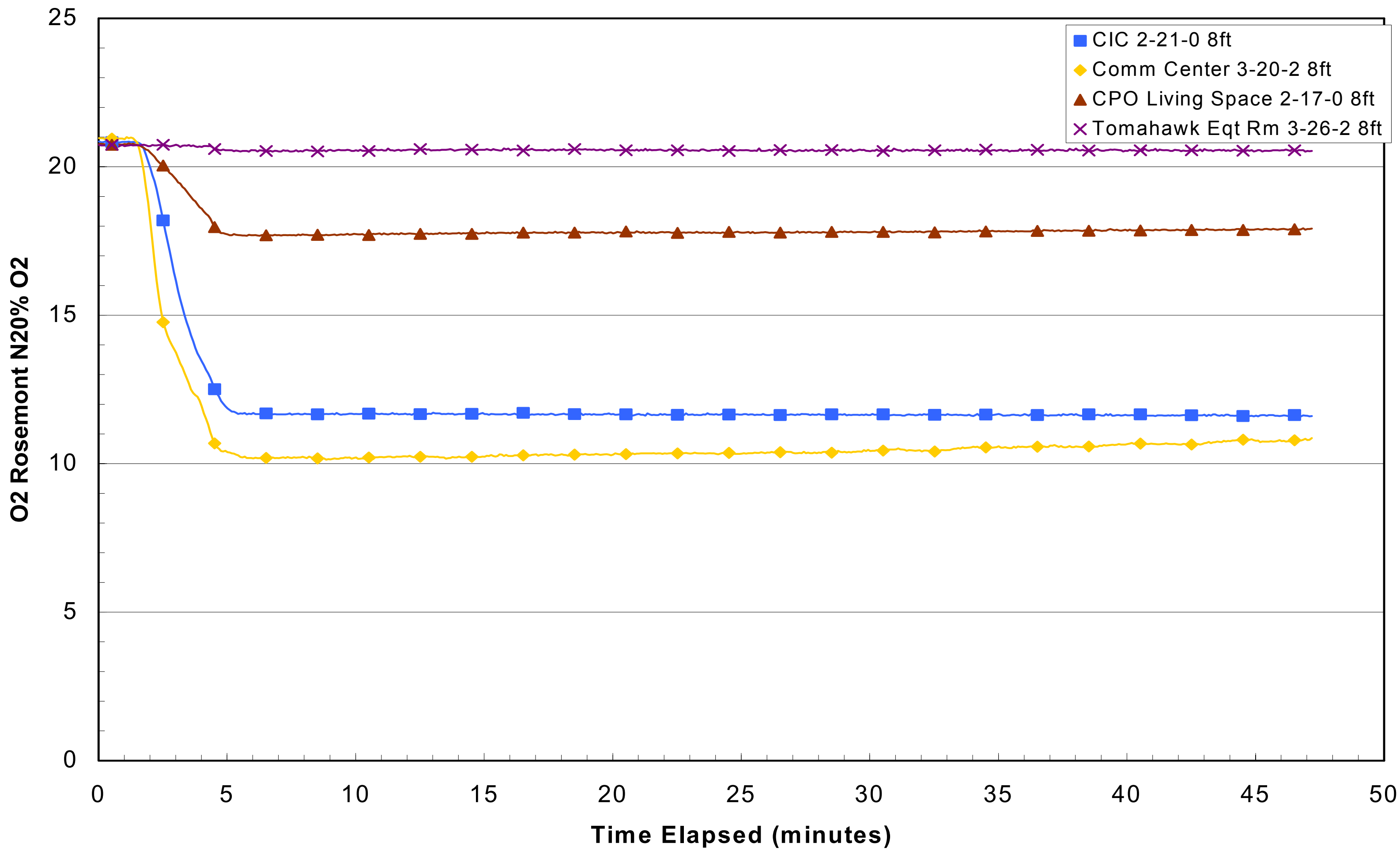


Fig. M29 – Oxygen Concentrations, Demonstration arm3w07

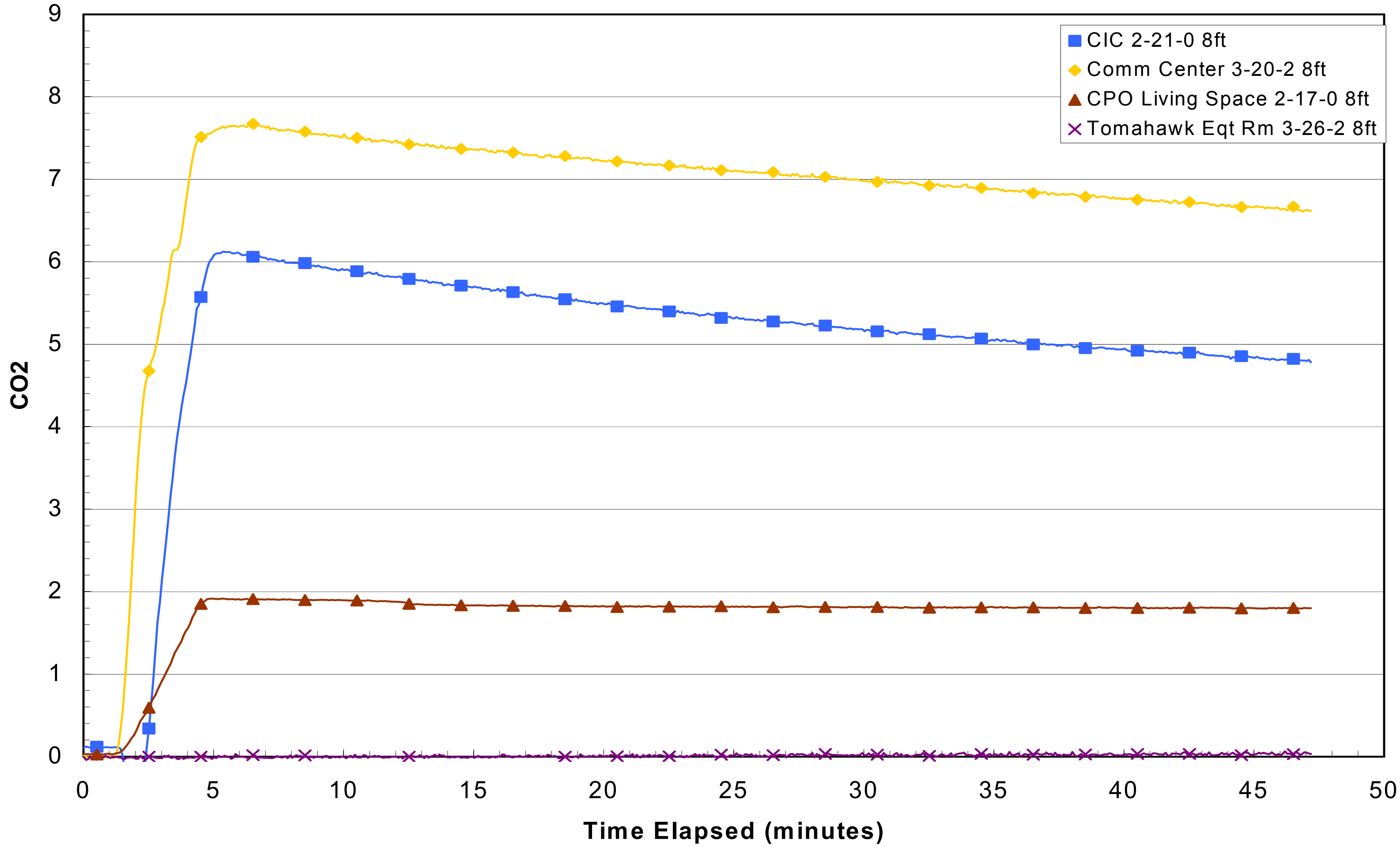


Fig. M30 – Carbon Dioxide Concentrations, Demonstration arm3w07

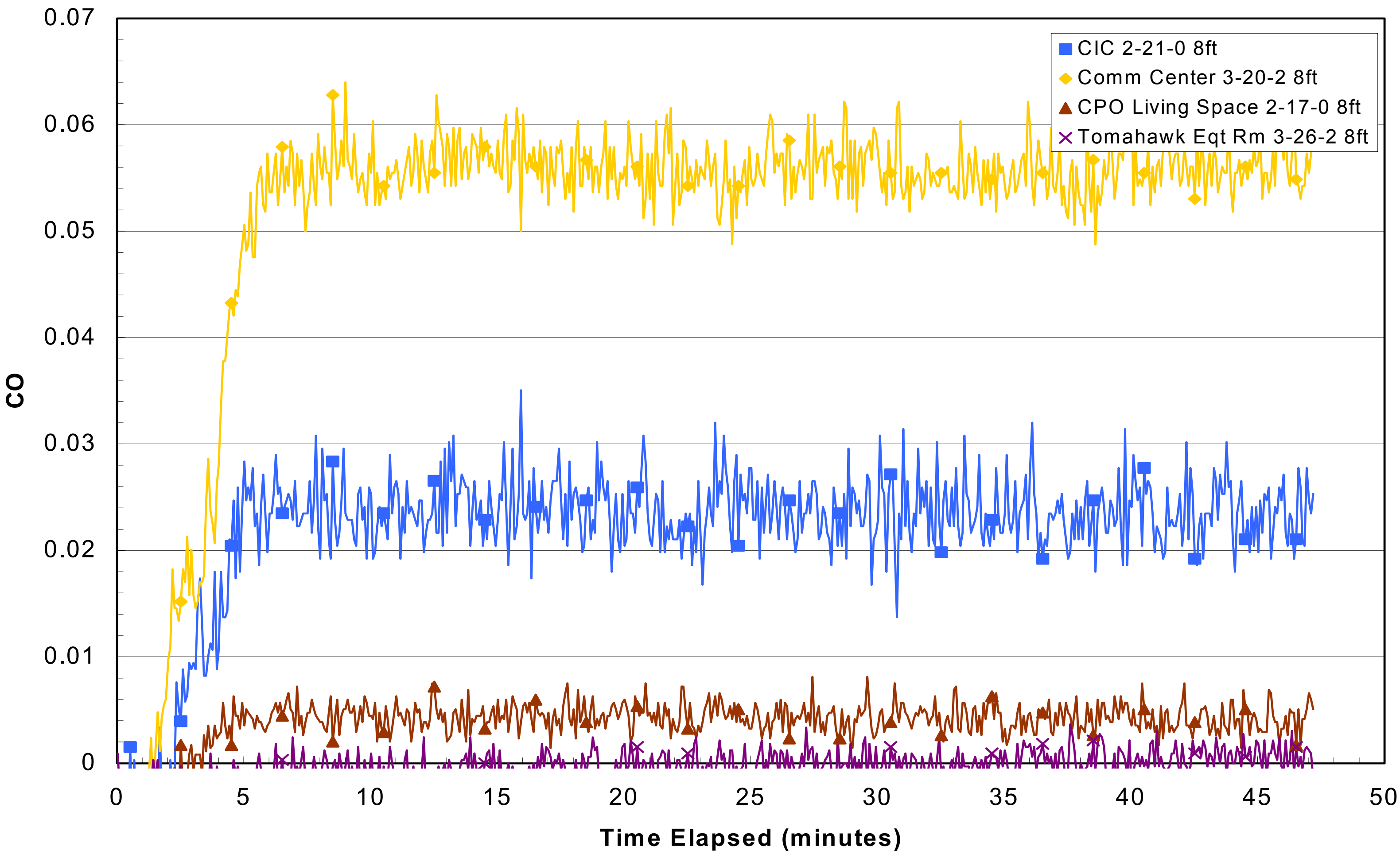


Fig. M31 – Carbon Monoxide Concentrations, Demonstration arm3w07

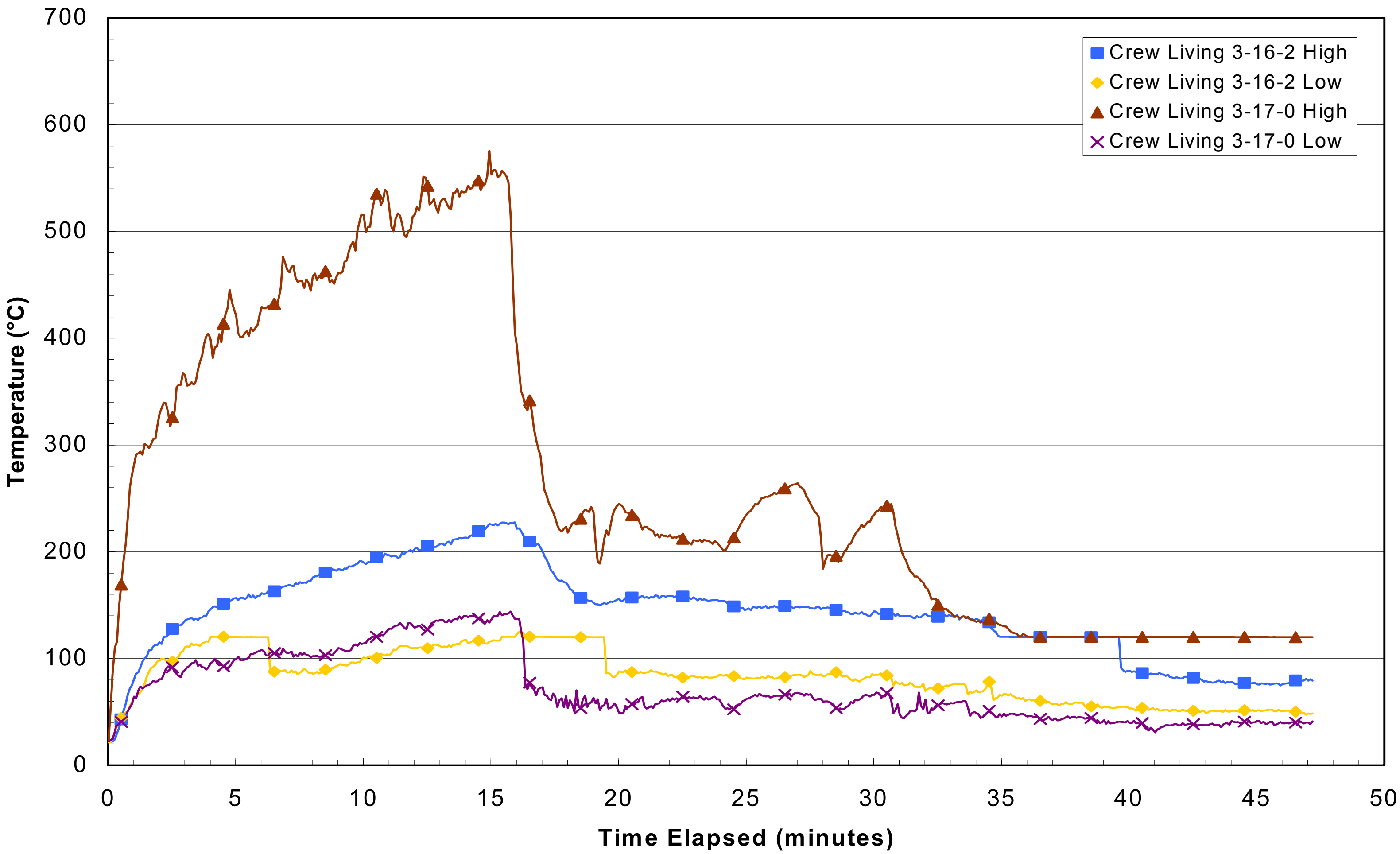


Fig. M32 – Crew Living Temperatures, Demonstration arm3w07

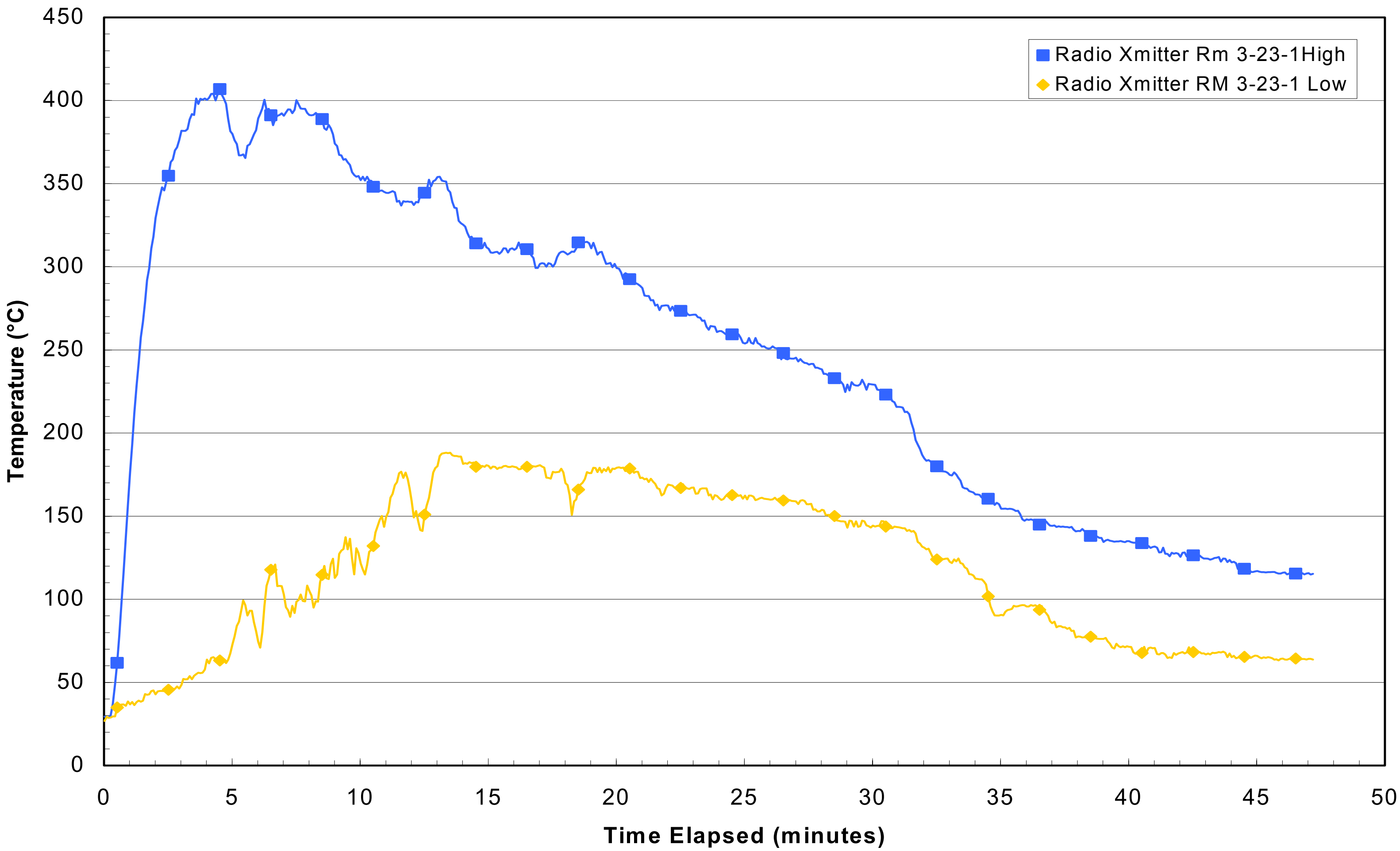


Fig. M33 – Radio Transmitter Room Temperatures, Demonstration arm3w07

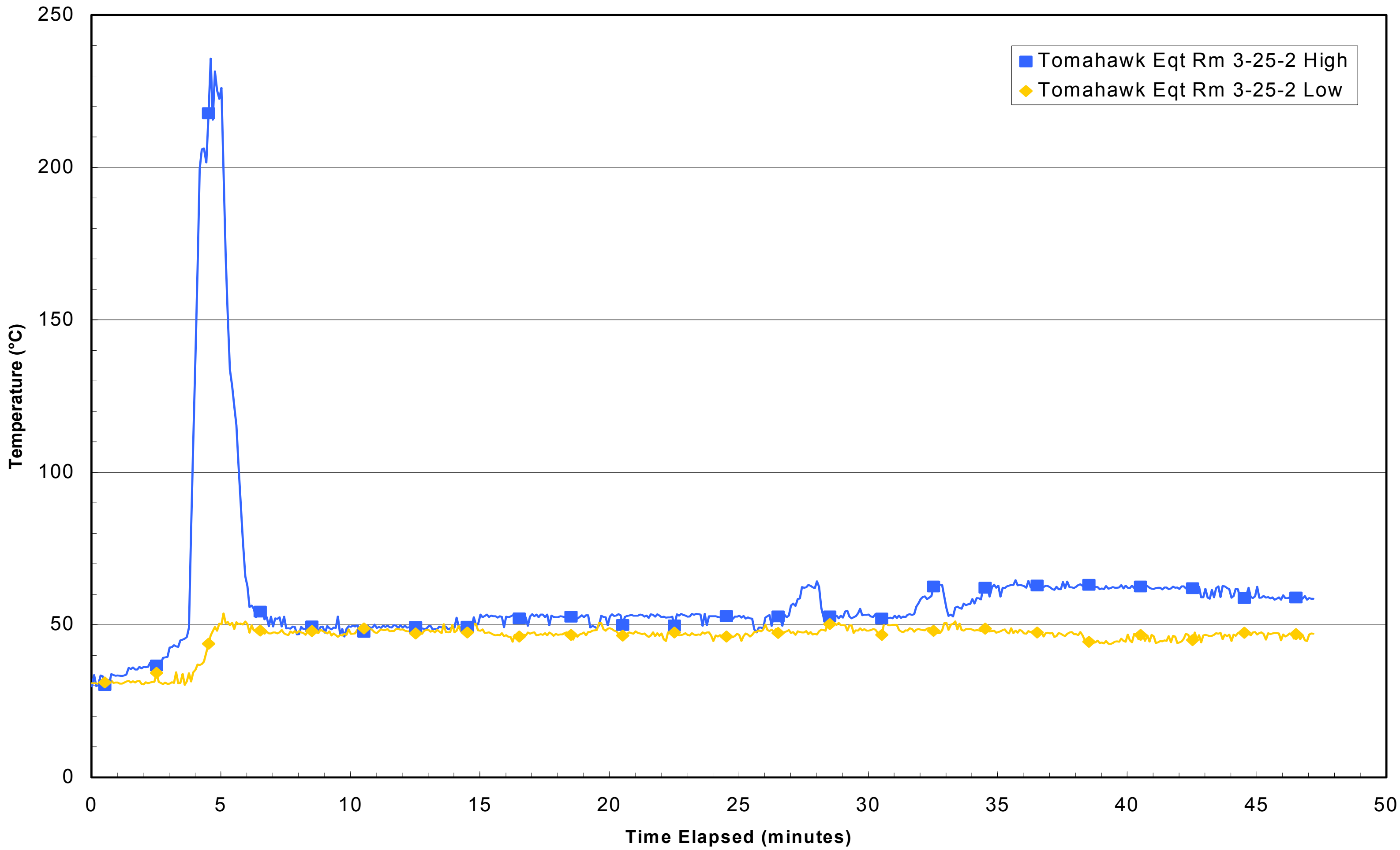


Fig. M34 – Tomahawk Equipment Room Temperatures, Demonstration arm3w07

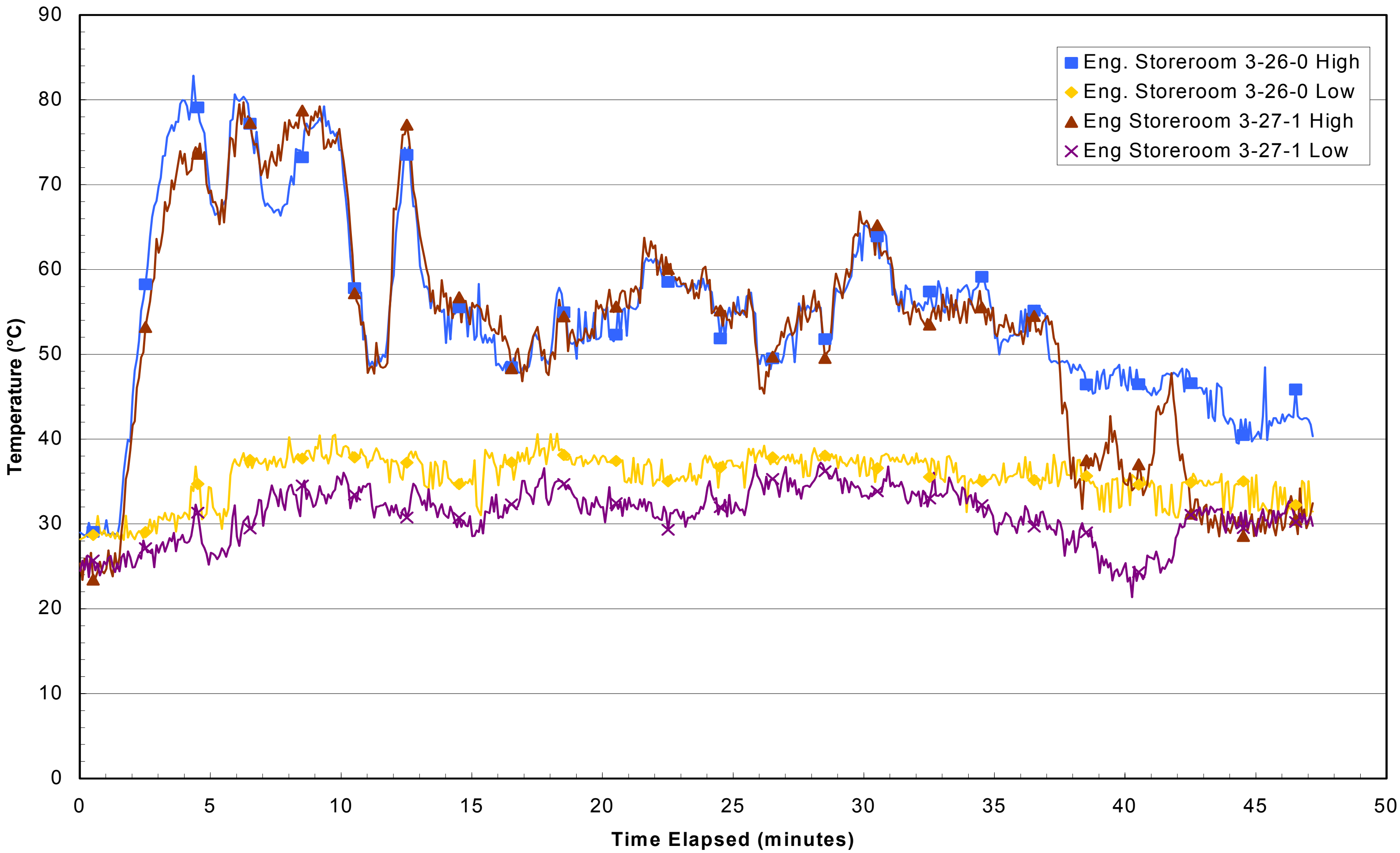


Fig. M35 – Engineering Storeroom Temperatures, Demonstration arm3w07

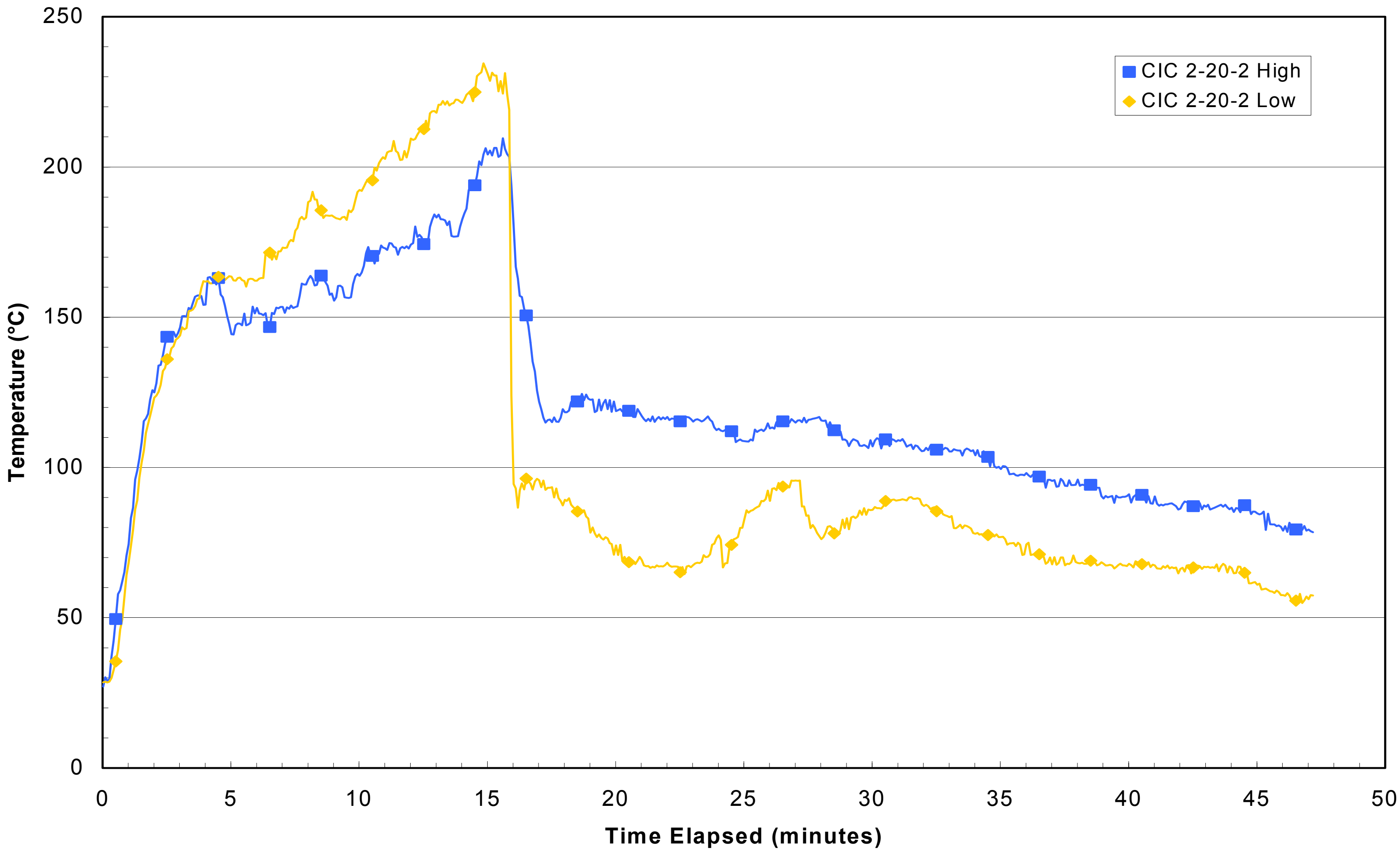


Fig. M36 – CIC Temperatures, Demonstration arm3w07

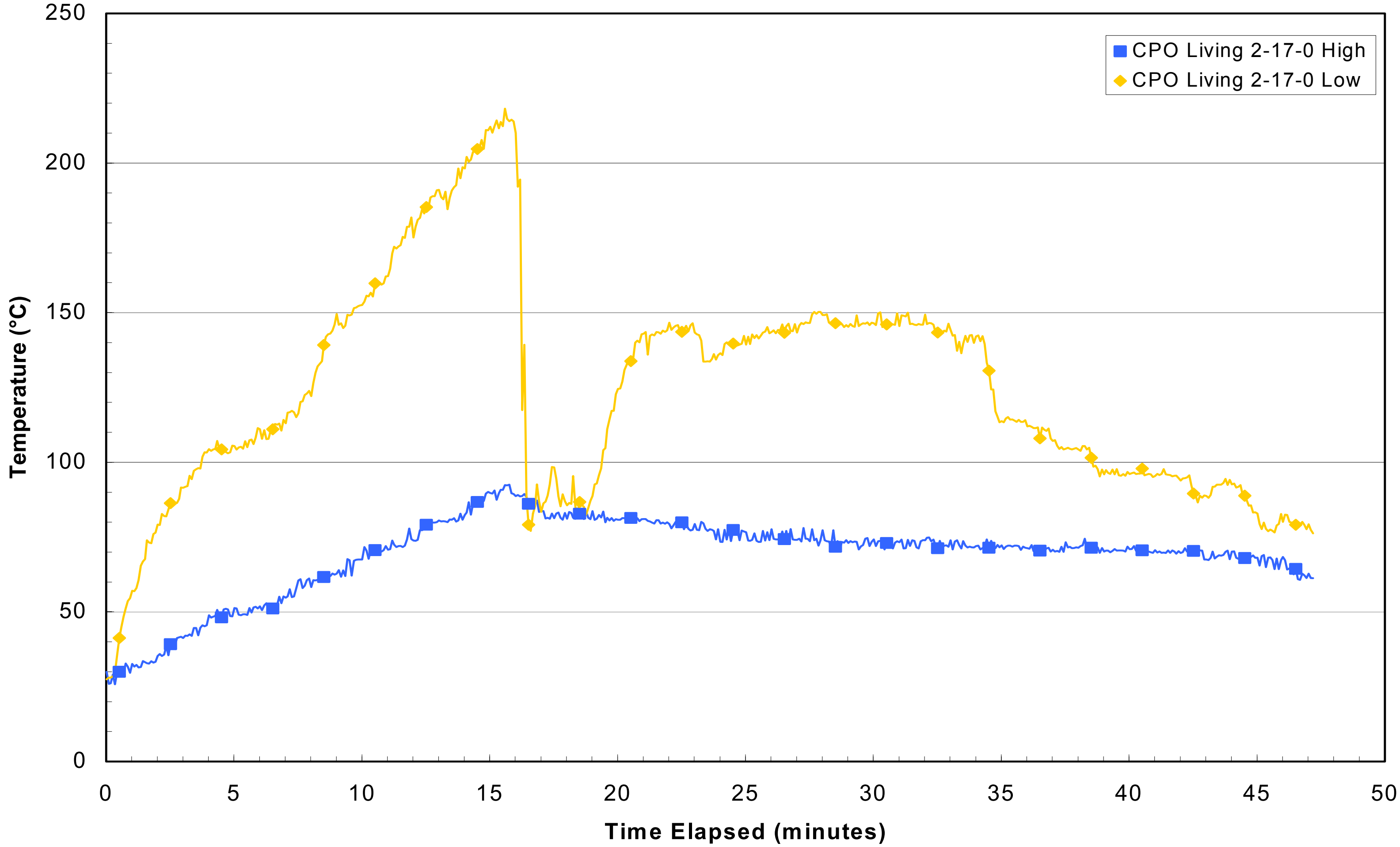


Fig. M37 – CPO Living Temperatures, Demonstration arm3w07

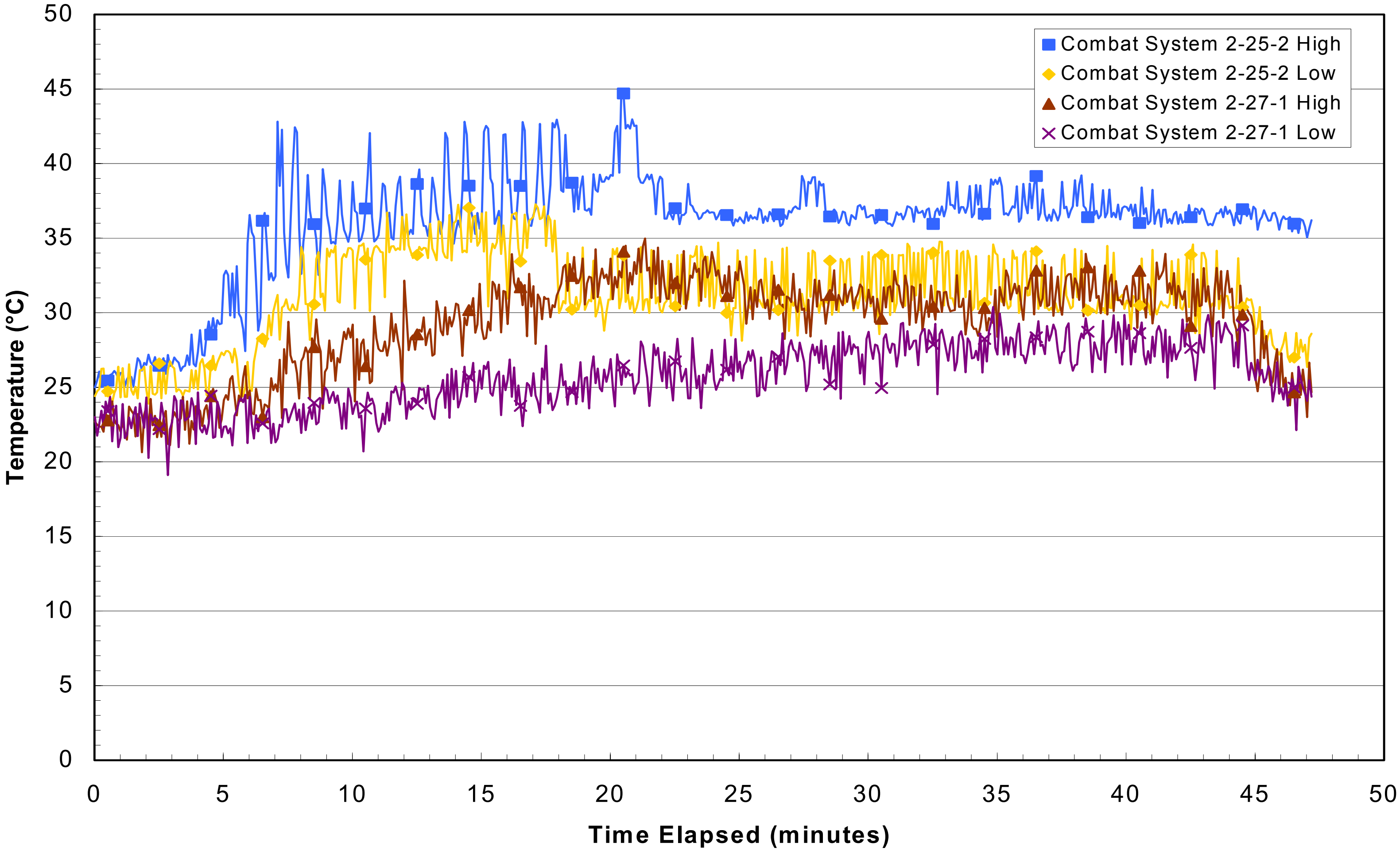


Fig. M38 – Combat Systems Office Temperatures, Demonstration arm3w07

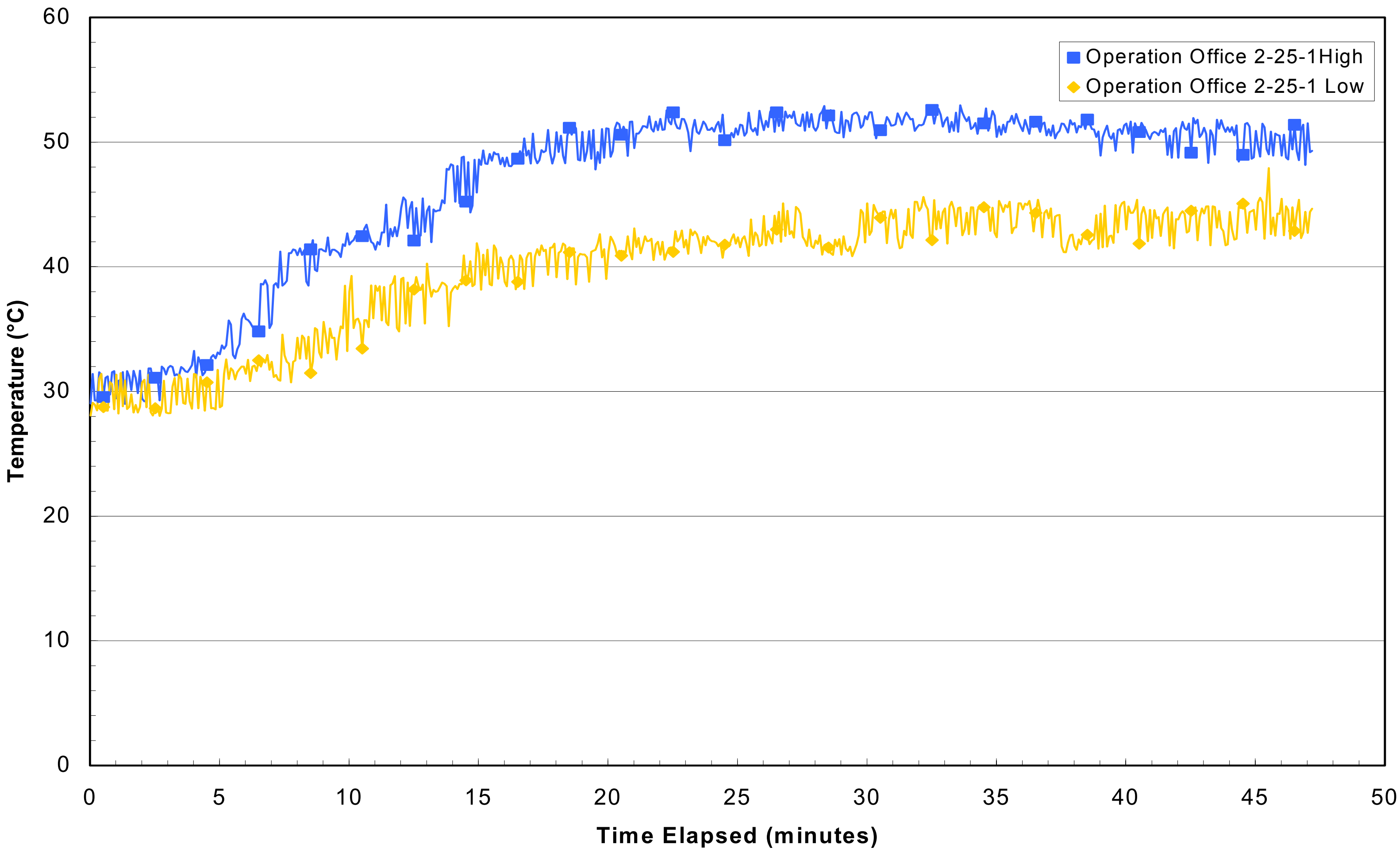


Fig. M39 – Ops Office Temperatures, Demonstration arm3w07

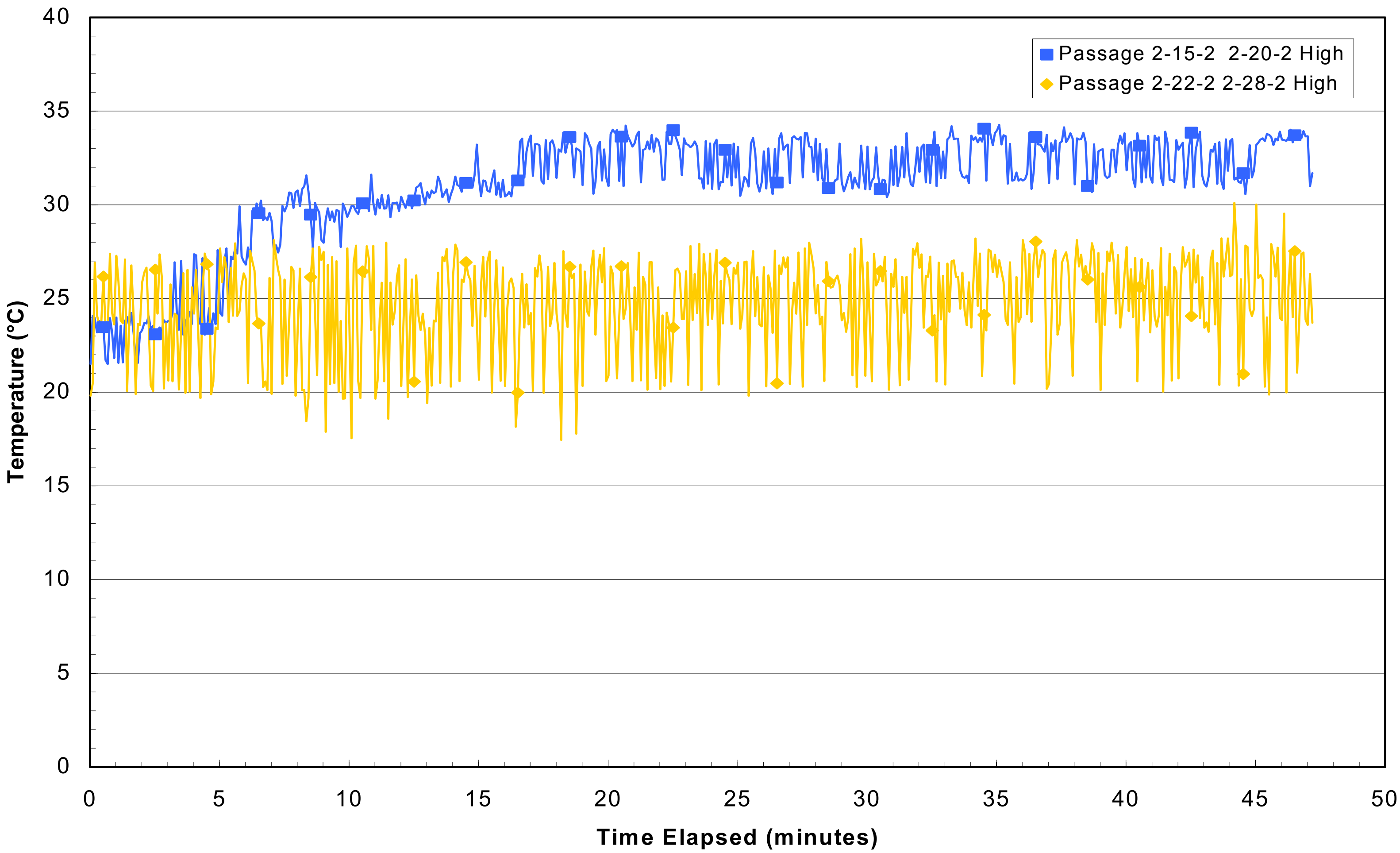


Fig. M40 – Second Deck Port Passageway Temperatures, Demonstration arm3w07

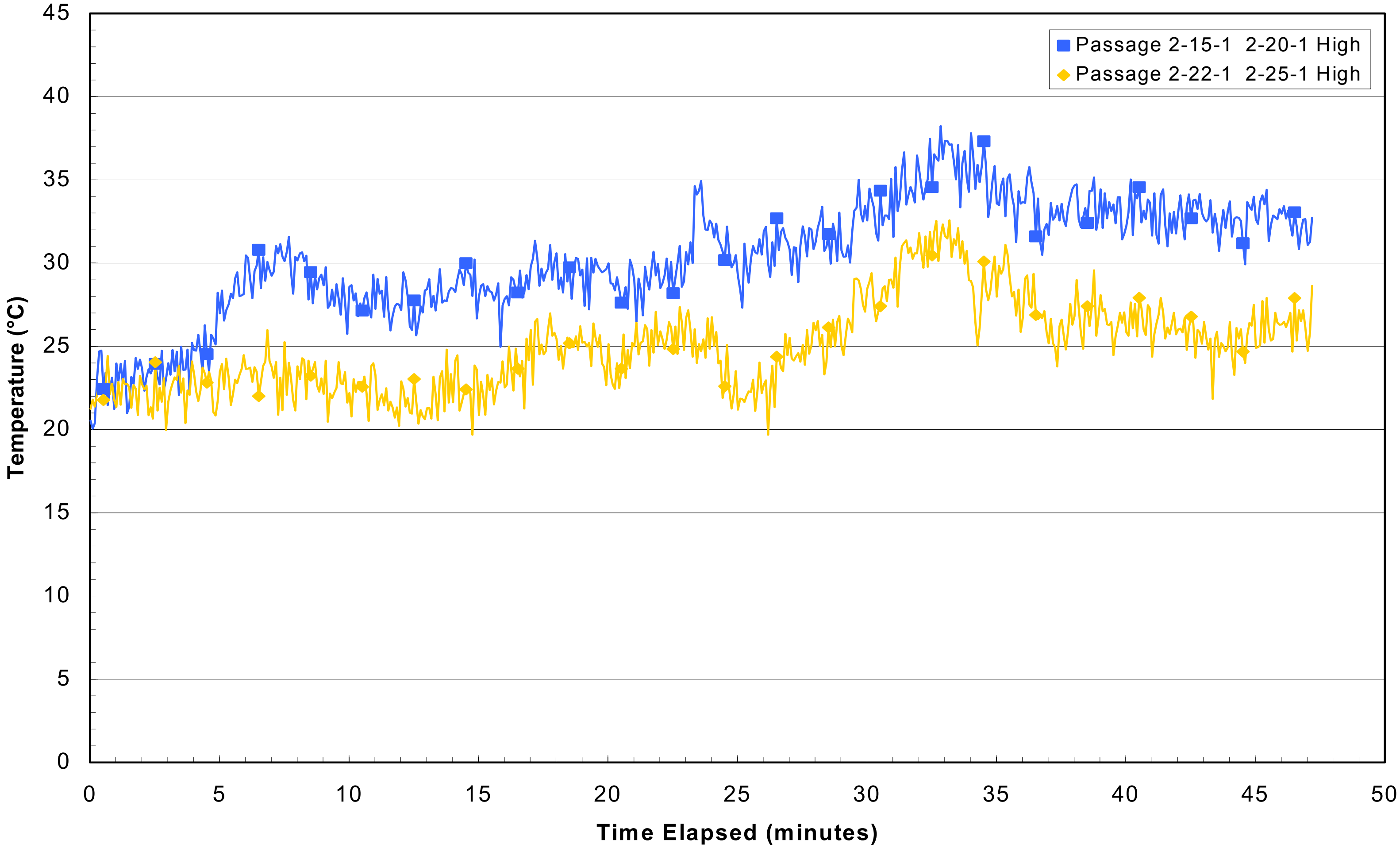


Fig. M41 – Second Deck Starboard Passageway Temperatures, Demonstration arm3w07

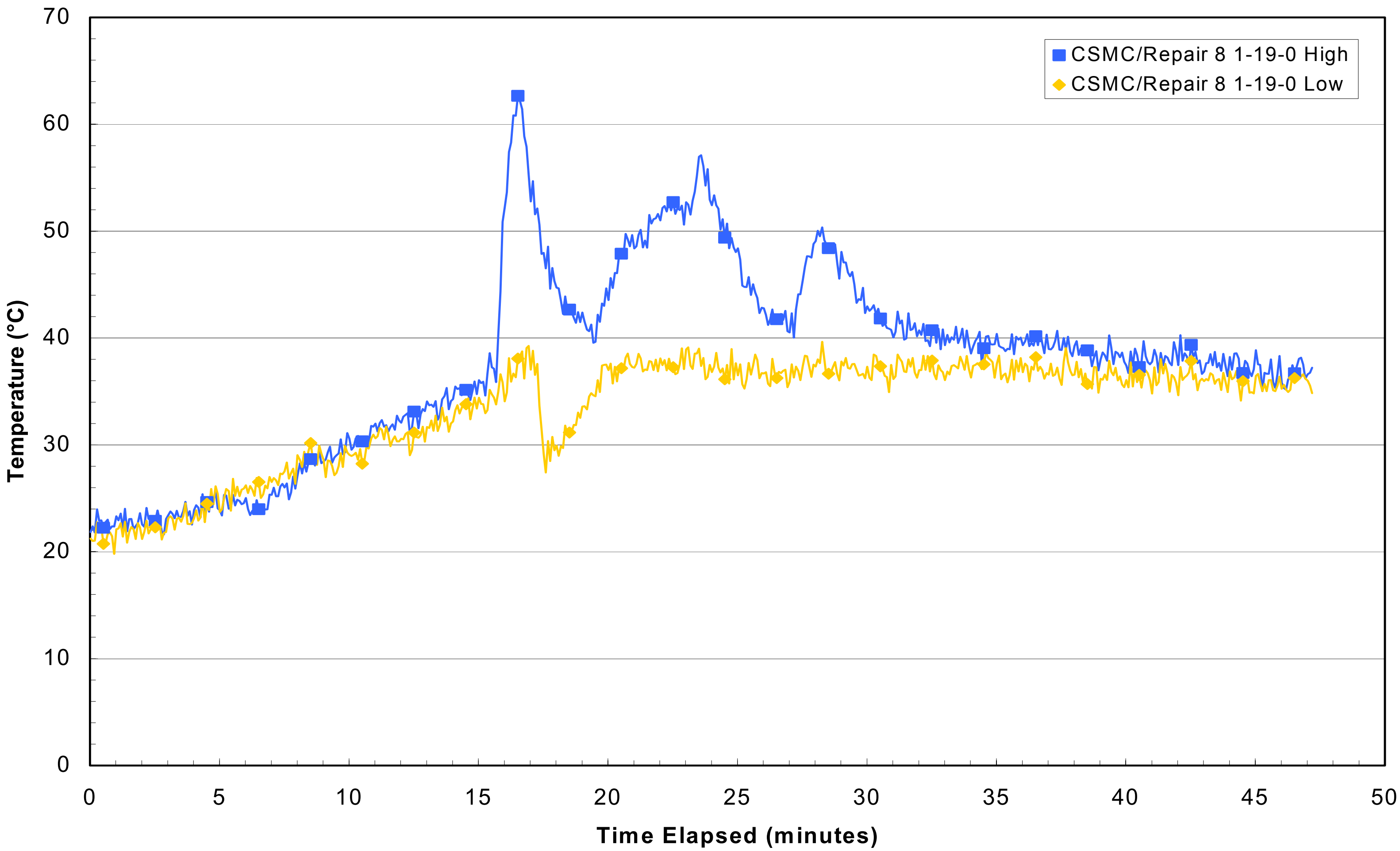


Fig. M42 – CSMC/Repair 8 Temperatures, Demonstration arm3w07

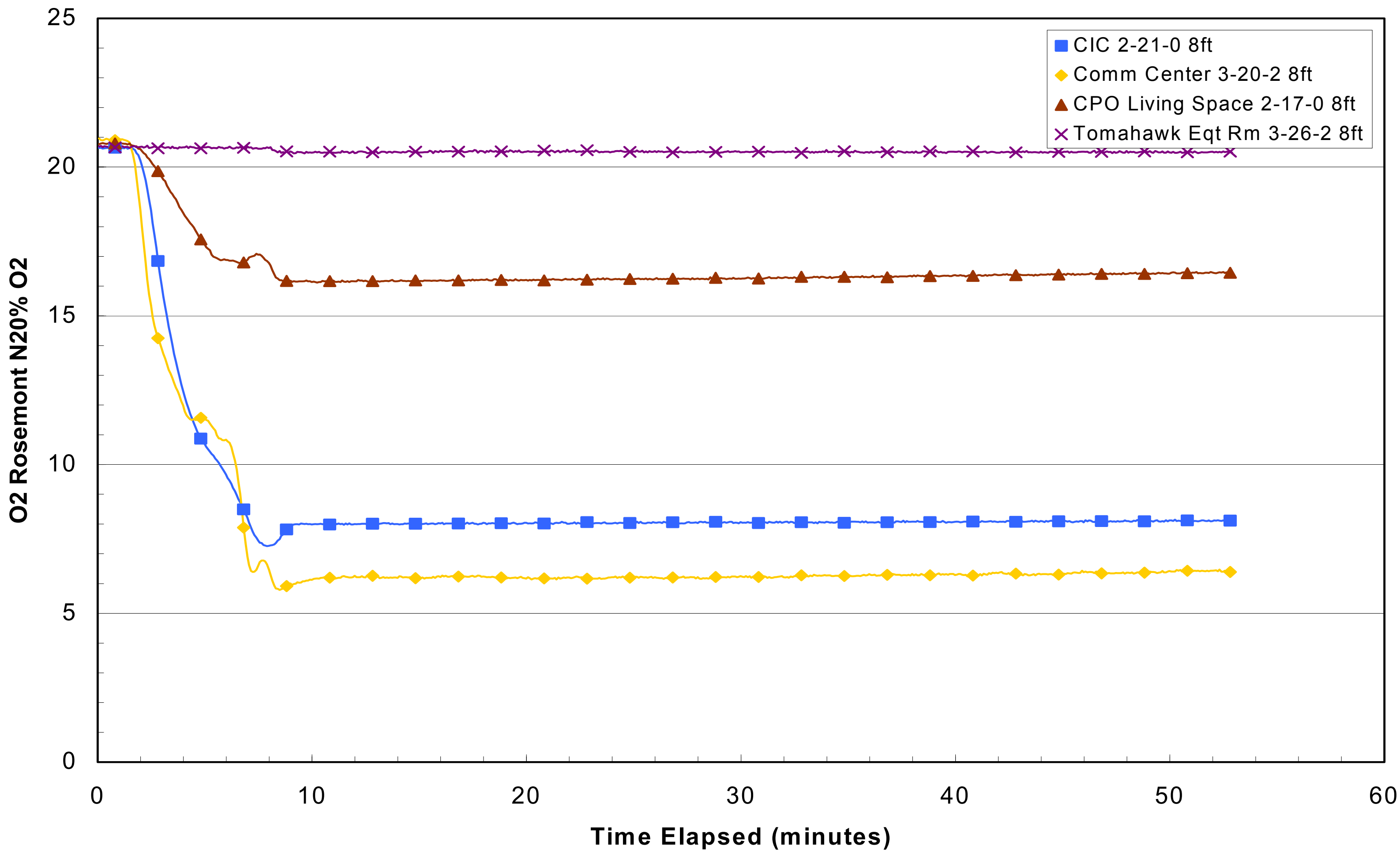


Fig. M43 – Oxygen Concentrations, Demonstration arm3w08

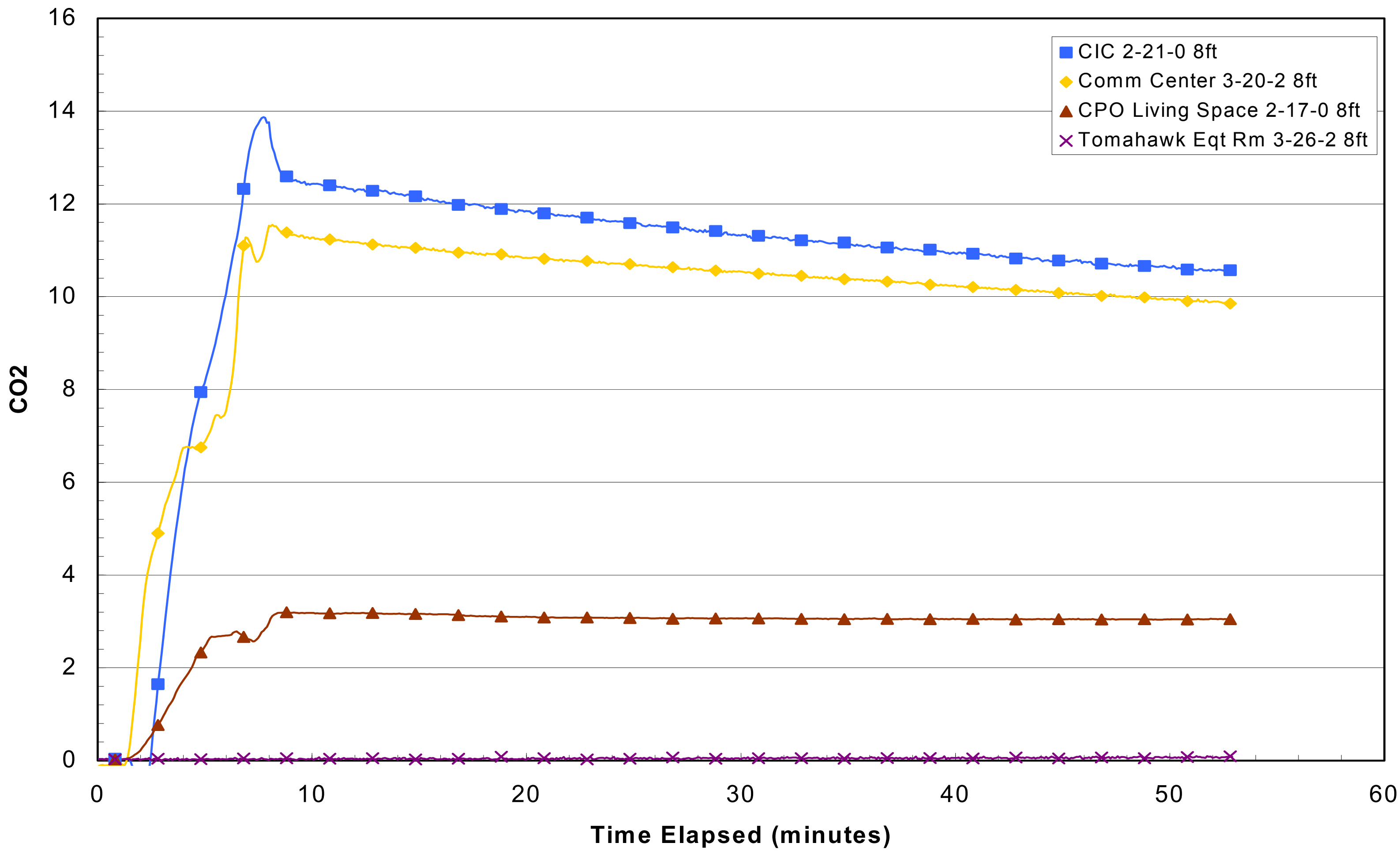


Fig. M44 – Carbon Dioxide Concentrations, Demonstration arm3w08

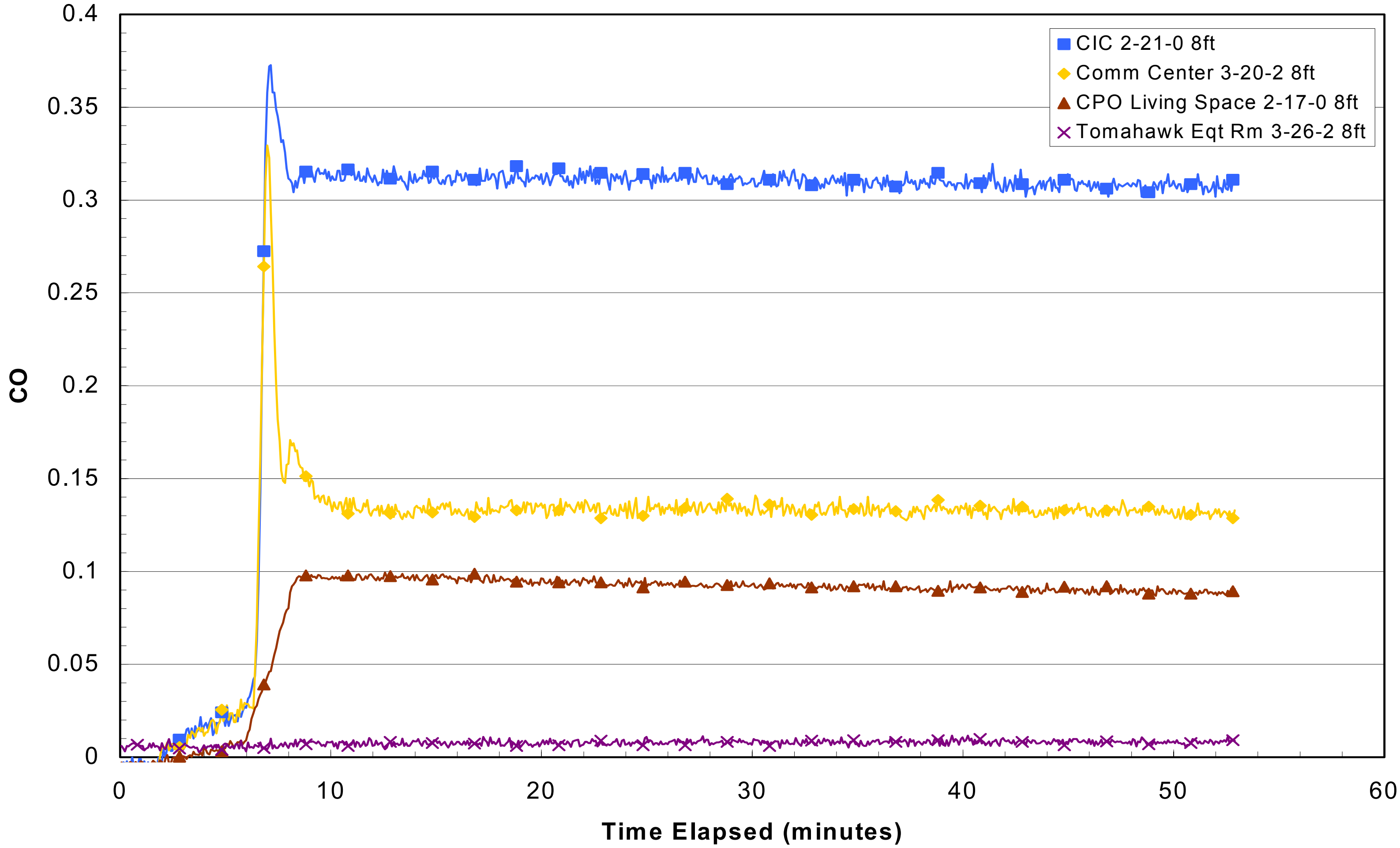


Fig. M45 – Carbon Monoxide Concentrations, Demonstration arm3w08

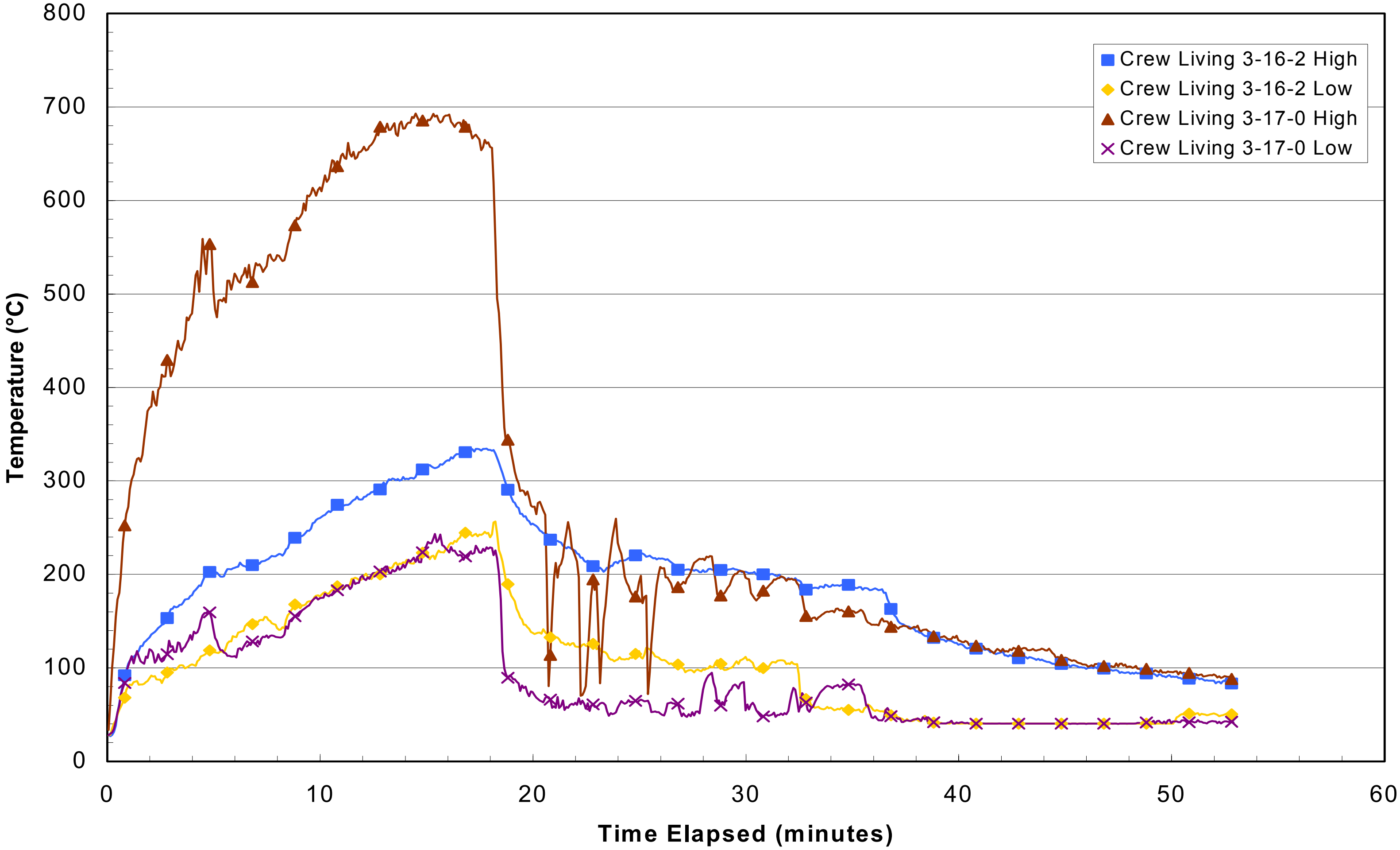


Fig. M46 – Crew Living Temperatures, Demonstration arm3w08

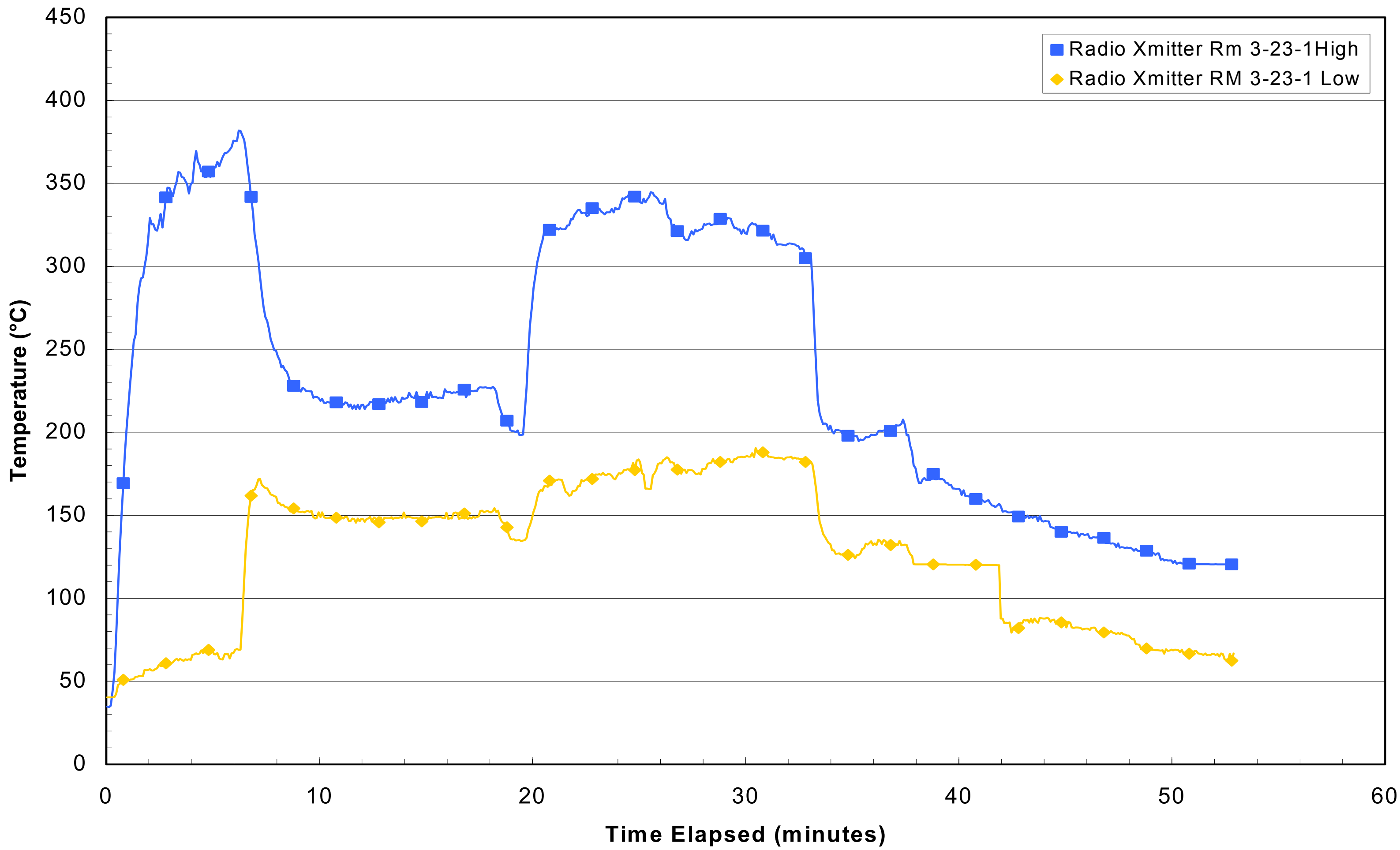


Fig. M47 – Radio Transmitter Room Temperatures, Demonstration arm3w08

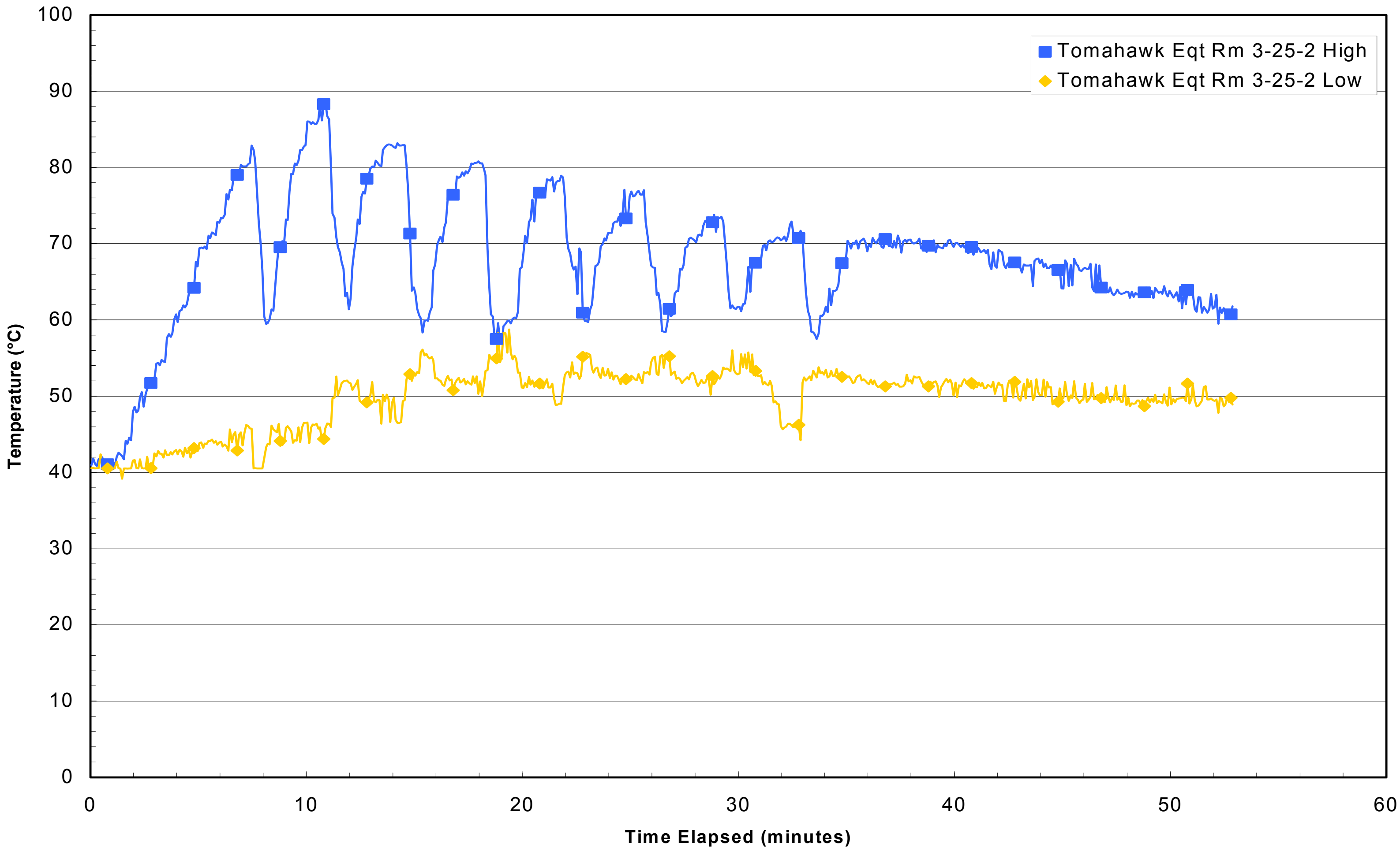


Fig. M48 – Tomahawk Equipment Room Temperatures, Demonstration arm3w08

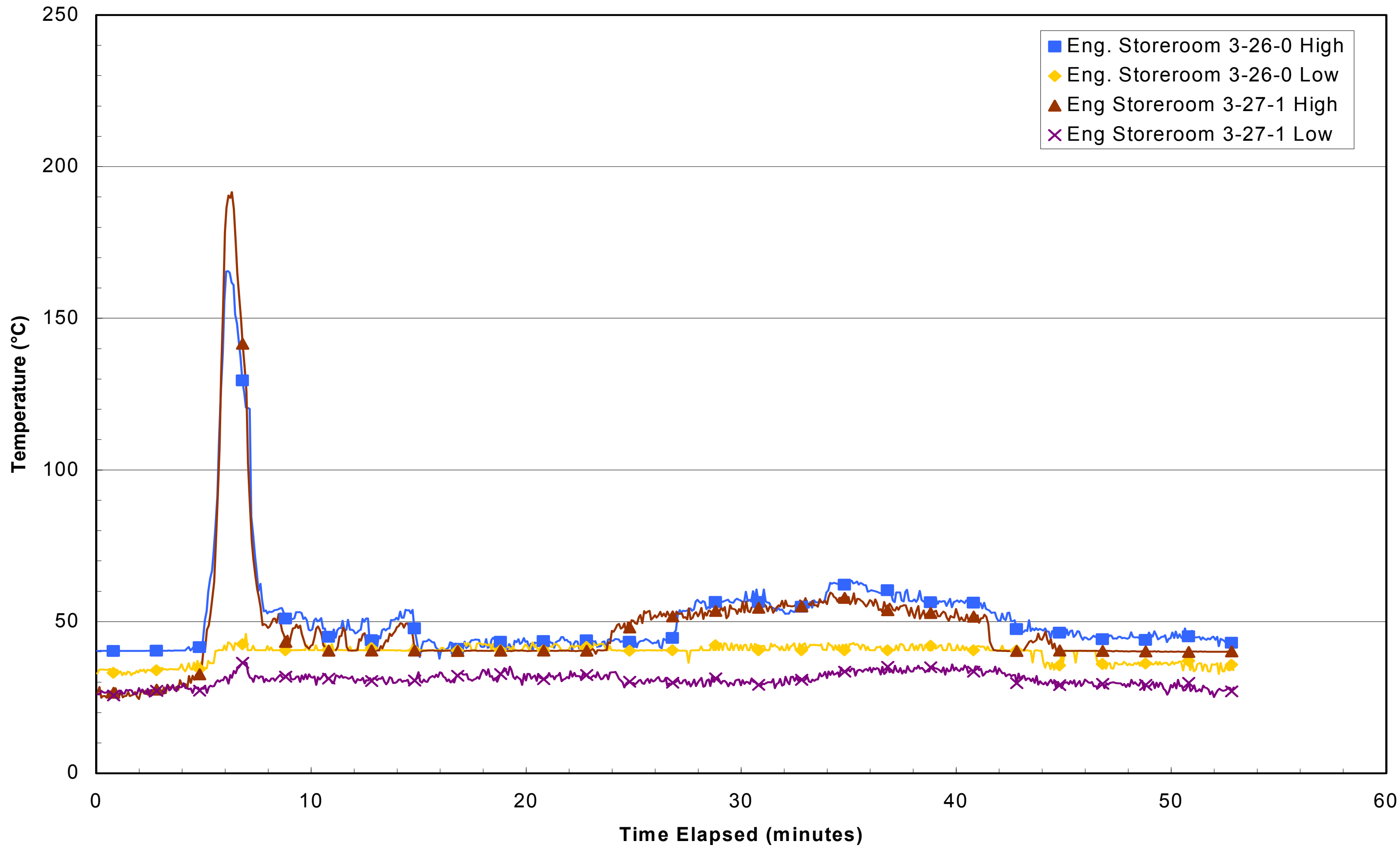


Fig. M49 – Engineering Storeroom Temperatures, Demonstration arm3w08

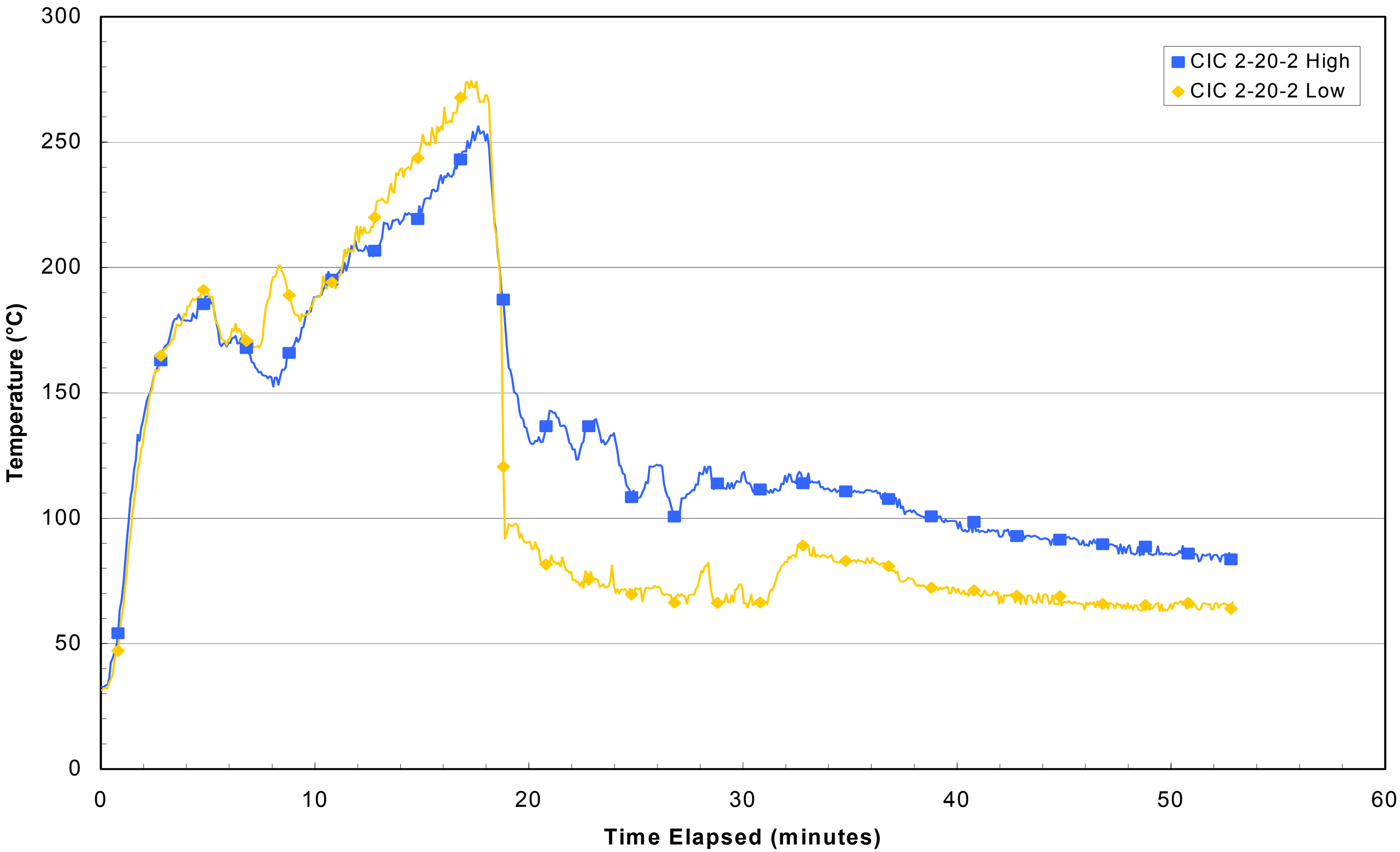


Fig. M50 – CIC Temperatures, Demonstration arm3w08

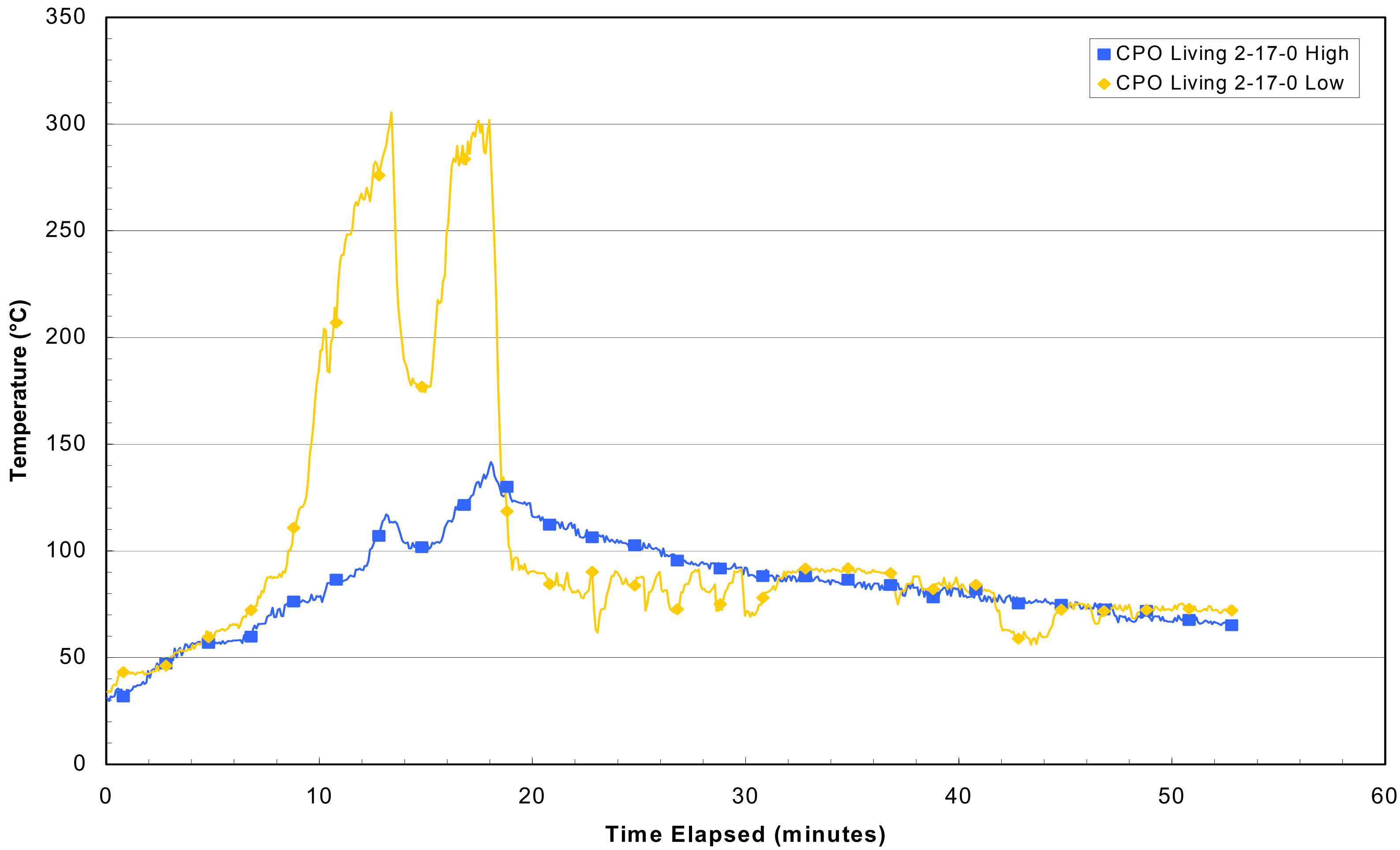


Fig. M51 – CPO Living Temperatures, Demonstration arm3w08

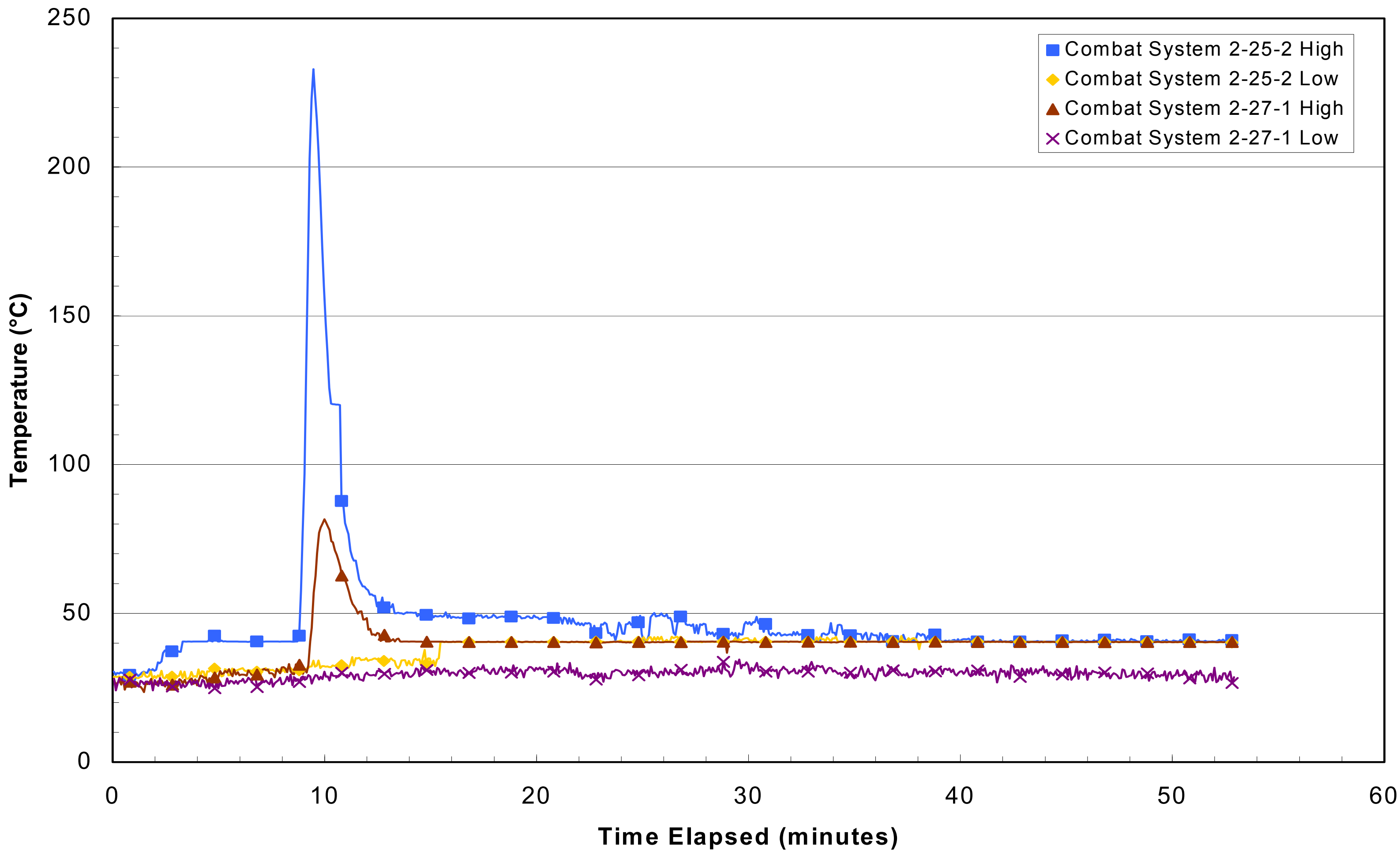


Fig. M52 – Combat Systems Office Temperatures, Demonstration arm3w08

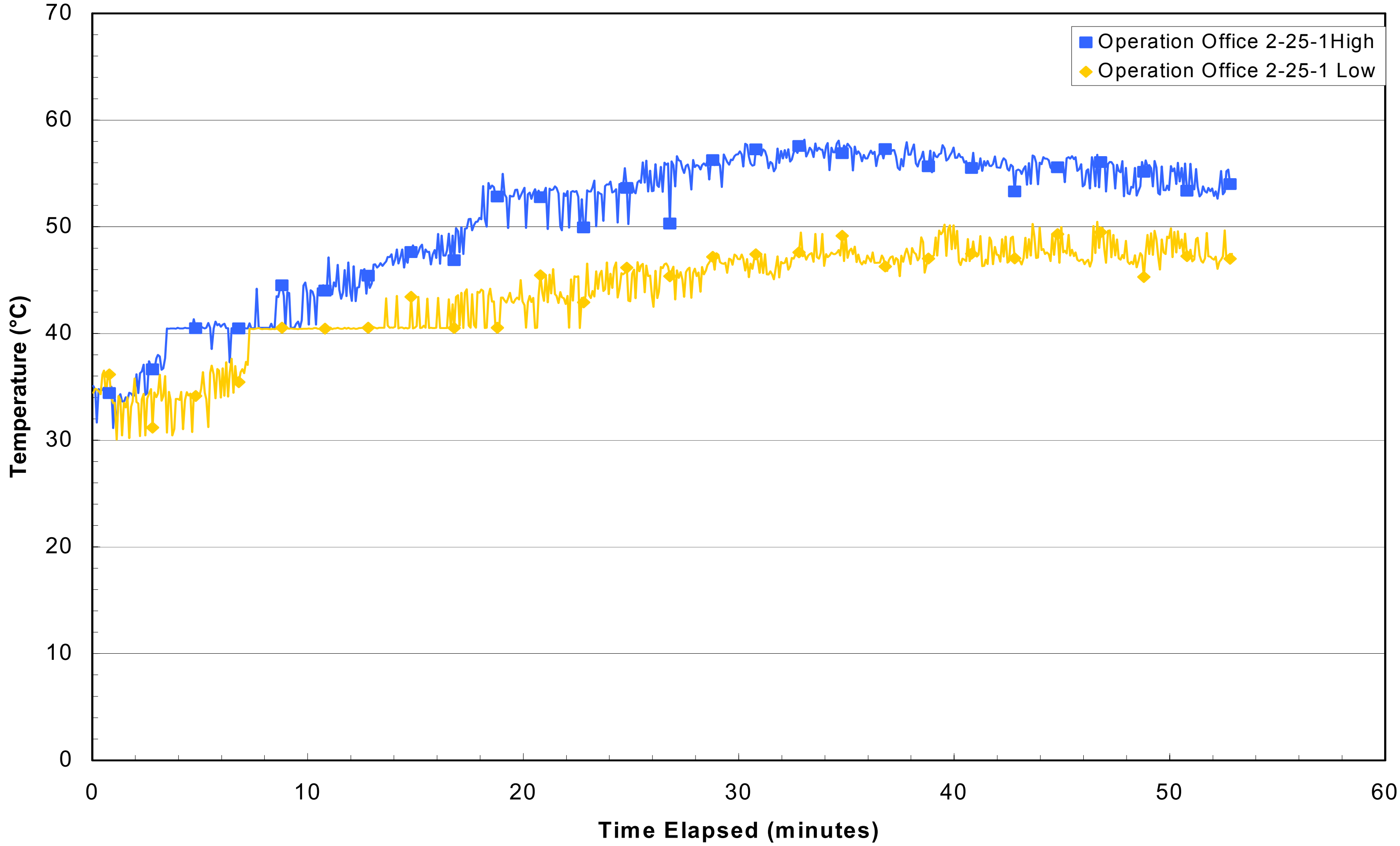


Fig. M53 – Ops Office Temperatures, Demonstration arm3w08

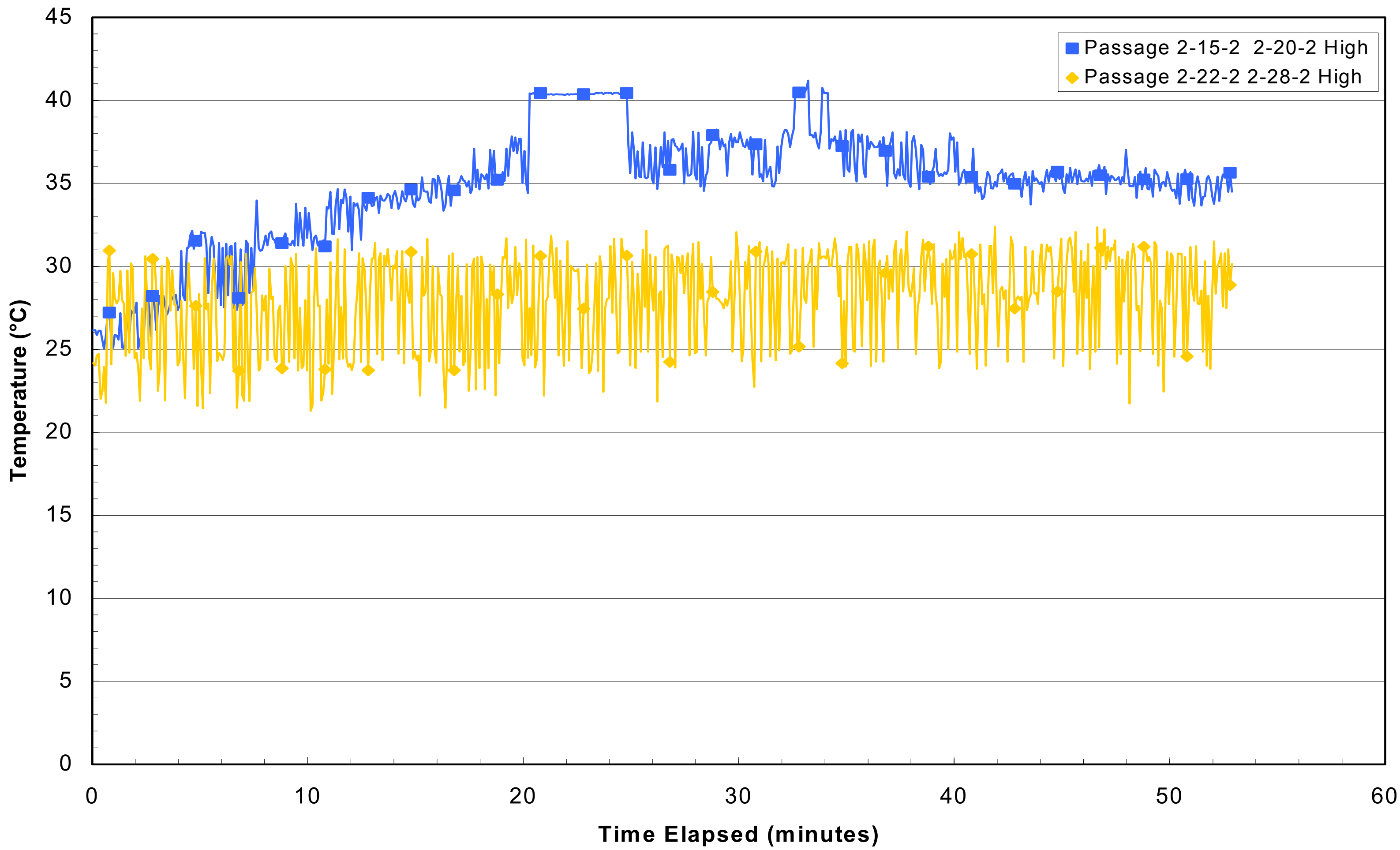


Fig. M54 – Second Deck Port Passageway Temperatures, Demonstration arm3w08

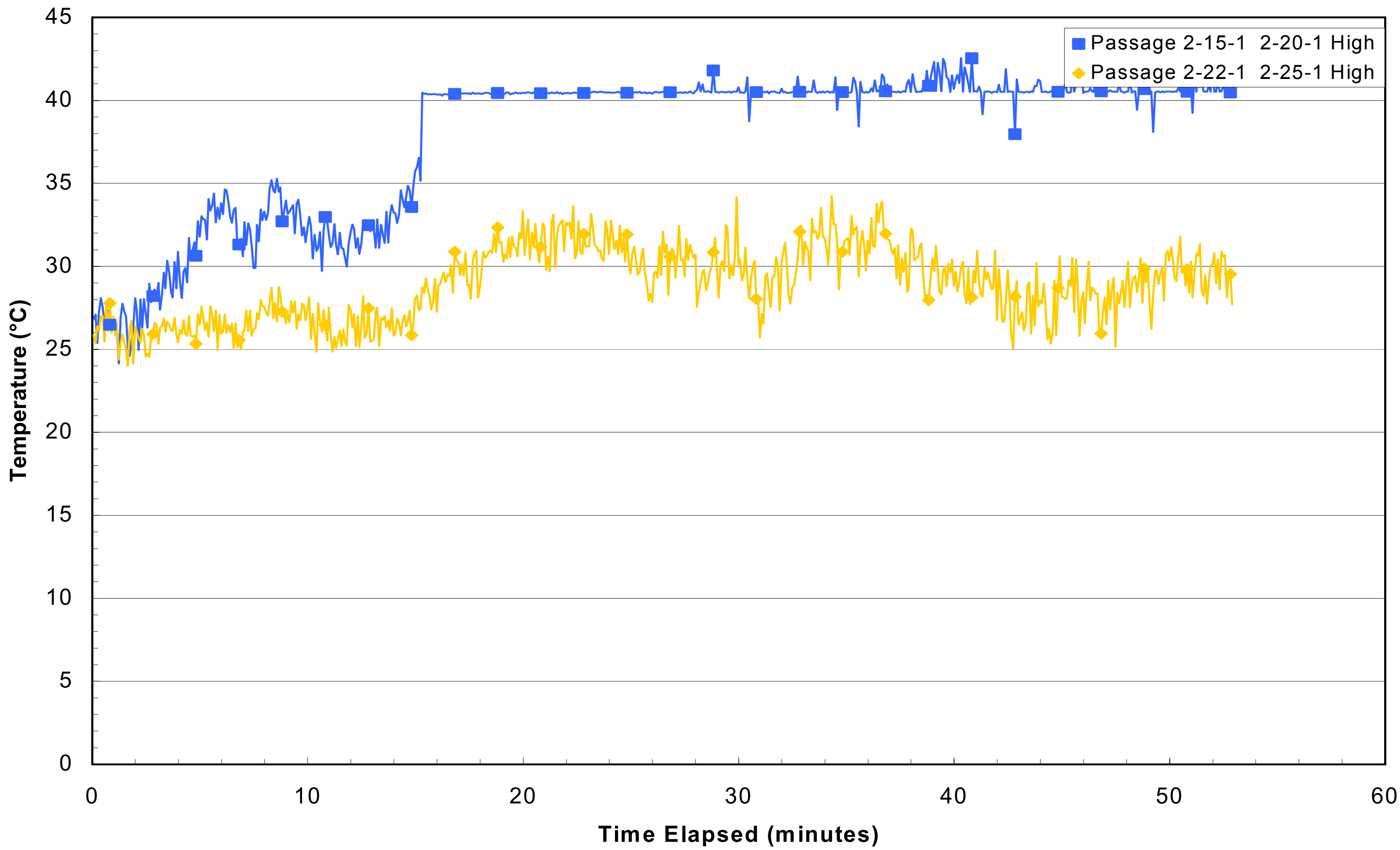


Fig. M55 – Second Deck Starboard Passageway Temperatures, Demonstration arm3w08

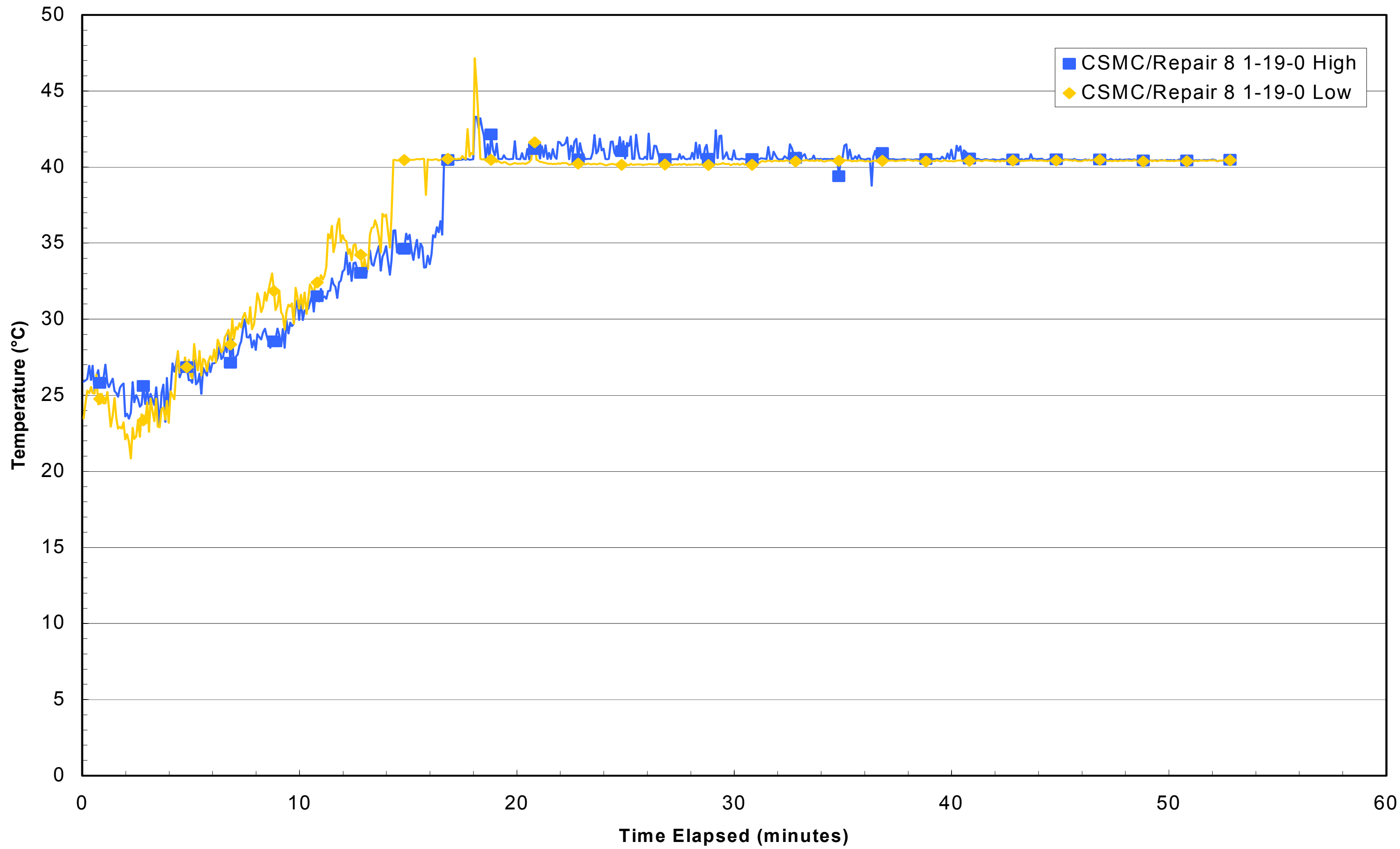


Fig. M56 – CSMC/Repair 8 Temperatures, Demonstration arm3w08

Appendix N - Test Participant Comments

1. General

- Mechanical and electrical system isolation is not currently accounted for anywhere in the Damage Control systems. An automated system much like the smart valves (fire main control system) would work.
- Minimize Repair Locker manning with the automated systems. Only one person is needed in the Repair Locker.
- It is extremely important that the system (network, sensors, etc.) be reliable. There were a number of times when different systems appeared to lock up - including the video system, water mist and the SCS overall.

2. Supervisory Control System

- Decision Aids - Methods of smoke control, personnel routing/management, electrical/mechanical isolation.
- Missile Hit Information (Pre-Hit Information) – How valuable/accurate is this information? Will this system interface with Combat Systems? If so, what data is transferred?
- Audible Alarms would be beneficial to identify new, significant events. This would eliminate events occurring without the DCO's knowledge. The SCS may already be set up to do this, recommend using different sounds for different events.

3. Water Mist Suppression System

- Personnel felt that the water mist system worked well to cool spaces and extinguish fires.

4. Fire Main Control System (Smart Valves)

- In general, extremely positive feedback received on fire main control system. Personnel thought this system worked well and should be used.
- When a fire main rupture occurs, the system automatically detects and isolates the rupture, however unless the DCO "catches" the rupture isolation as it is occurring (i.e., sees the text flash on screen), the ruptures goes unnoticed. In addition, when the rupture is isolated, the SCS creates a list of fire plugs which are out of service. This list of fire plugs is displayed under the suggested action of **each** potential fire. For example, in the case where we had 6 out of service fire plugs for 4 different spaces, the DCO has to "pass the word" for 24 pieces of information or at a minimum click 48 times under suggested actions to clear this list. This is cumbersome. Suggest having a small window pop up informing DCO (with audible) of rupture and unusable fire plugs. This window could be minimized to an icon which would remain on the screen. The list of unusable fire plugs should be accessible until the fire main has been repaired.

5. **Smoke Ejection System (SES)**

   - Most ships don't have smoke ejection system like that used on the SHADWELL. Ships should be designed to accommodate smoke control methods or have the supervisory control system pre-programmed with specific configurations to eject/control smoke.

6. **Video System**

   - Video input is very effective. It is "essential" for everyday use as well as damage scenarios.
   - Current setup is somewhat cumbersome. Video takes approximately 10 seconds to pop-up on screen. The DCO had no way to eliminate video that was non-functioning. Instead of being able to constantly monitor important spaces (with available video), there were times when 4 or 5 blank video (non-functioning) screens appeared.

7. **Door Closure System**

   - The management and setting of Zebra is a huge headache on any ship. Any system which helps to reduce this is helpful. Suggest developing a closure management system which automatically determines what is set and what isn't. Automatic closure of dampers, valves, etc. would also be helpful.

8. **Communications**

   - Verbal communications should be eliminated/reduced. The damage control system falls apart because of bad verbal communications. A 'palm-pilot' type system with a tracking capability would be ideal for the investigators. This wireless device would be tied to the network and would provide input from the investigators to the SCS. Verbal communications between DC Central and the investigators should remain, but should be used as a backup.
   - Implementation of a dual communications headset, which allows multiple access to different circuits. Any of the DC Central Watch Stations can punch in to a circuit and listen to the communications on that circuit.
   - Originally communications between the investigators and DC Central was through the DCO. Found it better to use the DC Plotter/Comm Operator to communicate directly with the investigators. Also communications worked well between the Attack/Support Teams and Casualty Coordinator.

9. Personnel/Manning

- DC Plotter/Comm Operator - Role should be expanded to Investigator Coordinator. This would require more access to the supervisory control system (currently use plotter - which is somewhat limited - as input to the SCS). Additionally, multiple displays (similar to the displays provided to the DC Watch Supervisor) would be required.
- Investigators - Are key to the success of a reduced manning casualty, as they are the eyes and ears of the DCO. Their inputs provide the resources by which the DCO can make a decision.
- Additional personnel should be considered for non-automated DC systems such as mechanical/electrical system isolation and direct/indirect attacks. Also consideration should be given to tasks performed by DC personnel post event, such as de-watering teams, overhaul, and gas-free.

Appendix O – Fleet Fire Fighting and Damage Control Doctrine Evaluations – Background Information

The DC-ARM concept was first evaluated in 1998. Prior to this test series, tests conducted from 1991 through 1997 typically utilized between 15 and 20 persons for damage control operations.

The Fleet Doctrine Evaluation Tests, conducted in 1991, were performed to evaluate the methods of containment for major conflagrations [1]. Tests were conducted in the port wing wall of the ex-USS SHADWELL. Fires were created in Berthing 2 (large post-flashover fire ~11 MW) and RICER 2 (vertical fire spread simulated by a total of 3 wood cribs). Five boundaries (4 horizontal and 1 vertcial) were to be maintained during this test series. Temperatures exceeded 400°C (752°F) in RICER 2, and peaked around 150°C (302°F) in CIC (above RICER 2); temperatures in Berthing 2 were on the order of 800-1000°C (1472-1832°F). A total of 20 personnel were used to perform boundary cooling, indirect attacks and desmoking of the test space. The DC team was successful in performing the damage control operations, but the tasks performed were extremely labor intensive and required use of all personnel. In addition it was noted that good leadership and communication are vital to the success of the damage control team.

In 1992, Heat and Smoke Management/Fire Fighting Tests were performed to evaluate heat and smoke management doctrine, observe communications between the damage control personnel and assess manning of the Repair Locker [2]. Damage control tasks included locating the fire, setting fire boundaries, desmoking the area, and extinguishing the fire. During this test series approximately 15 damage control personnel were used to accomplish these tasks. Modest heat threats were simulated by a wood crib in CIC and pans containing diesel and heptane fuels in the forward portion of this same space. Temperatures in the main fire compartment exceeded 600°C (1112°F), while temperatures in adjacent spaces (specifically area above CIC) exceeded 300°C (572°F). Fire boundaries (above and around CIC) were maintained. This test series demonstrated that additional personnel were needed to for desmoking duties. In addition, it was recommended that personnel should be flexible in their assigned duties, allowing other tasks to be performed.

The Fire Fighting and Doctrine Control Equipment Evaluation Tests were conducted in 1996, to evaluate new tactics, procedures and equipment (particularly SCBAs) [3]. Fires were simulated using wood cribs and particle-board panels in Berthing 2 on the 3rd deck, and the Storage compartment on the 2nd deck. A total of 17 people were used for damage control operations, which included indirect and direct attacks of the fires. This was the first test series in which direct attacks of the fires on both the 2nd and 3rd decks was evaluated. Additionally the test area was significantly expanded as compared with the area used during the test series discussed in the preceeding paragraphs. The direct attacks of Berthing 2 and the Storage compartment proved to be difficult; complementary indirect attacks were required to help cool these spaces. As this test series focused more on evaluating new equipment, boundary maintenance was not performed. Temperatures in the main fire compartments, Berthing 2 and Storage, exceeded 400°C (752°F) and 700°C (1292°F), respectively.

As part of the DC-ARM program the test area on the ex-USS SHADWELL was significantly expanded to provide a more realistic mock-up of a DDG 51 class ship between FR 126 and FR 174, covering 5 decks (main-hold levels) [4]. In addition to a larger test area, the

threats and casualties became more complex. This included more severe fires and simulated damage to the fire main. Due to these changes, the number of personnel involved in damage control operations increased slightly in 1998 from 20 people to 27 people. DC personnel were required to perform the same tasks as in the previous tests (investigate test area, set fire boundaries, desmoke passageways and extinguish fires). Isolation of fire main ruptures was an additional task performed by the damage control team. Fire boundaries were required around CIC and the Comm Center, in approximately 11 compartments and passageways. Boundaries were manually set and maintained within 50 minutes of the start of the demonstration. Fire main ruptures were manually isolated within 22 minutes. Overall the PDA was contained with 55 minutes.

For the FY 00 and FY 01 DC-ARM demonstrations the number of damage control personnel varied from 21 in 2000, to 24 in 2001 [5]. It should be noted that the main focus of the FY 00 demonstrations was not manning; a structured manning organization was not thoroughly evaluated. Prior to the FY 00 demonstration, the test area was again expanded to extend the test area vertically and horizontally. Vertically, AMR No. 1 was included in the PDA, which provided for a three-deck damage scenario. Horizontally, additional APDA compartments were included in the test area.

For the FY 00 demonstration, the number of personnel used for damage control operations was reduced to 21; this reduction was the result of the advanced systems developed for damage control. As these systems were operated in the remote-manual mode, the number of personnel used to activate these systems increased, as each system required an “operator”. Significant reductions in times to complete DC tasks were observed during this test series. The time to set boundaries ranged from 2 minutes (using the water mist system in remote manual mode) to 7 minutes for manual boundaries. Fire main ruptures were isolated within 2 minutes. Overall the time to control the PDA was reduced from 55 minutes in 1998 to 38 minutes in 2000.

The FY 01 demonstration utilized automated DC systems and a refined DC manning organization to effectively manage wartime casualties. A total of 24 persons (3 more than used in FY 00) were utilized during this test series. The test area used in FY 01 was similar to that used in the previous demonstration. Additional damage was simulated as part of this test series, as flooding of compartments was simulated. Times to set fire boundaries using water mist occurred within 1 minute of the missile hit. These systems were automatically activated by the SCS as necessary. Manual boundaries were set within 8½ minutes; it should be noted that a delay in setting boundaries during the selected test occurred as a result of confusion regarding damaged fire plugs. Typically, shorter times to set manual fire boundaries, on the order of 4 minutes, were observed during the other FY 01 tests. Flooding was detected by the investigators and contained manually; times to contain flooding were on the order of 28 minutes. Overall the fires in the PDA were contained with 32 minutes.

Table O-1 - Summary of Fleet Fire Fighting and Fleet Doctrine Evaluation Tests

	Test Series (Date)	Manpower	Doctrine	Technology	Recommended Improvements
Historical Test Series - Pre DCARM	Fleet Doctrine Evaluation (FDE) Tests (1991)	Effectiveness of minimal response firefighting tactics with single hose line demonstrated. Number of persons required for fire boundaries varied. Leadership and communications critical in mass conflagration	Emphasize indirect fire fighting of PDA	Advantages of active desmoking during fire fighting was demonstrated	Need for integrated damage control identified (i.e. other casualties such as flooding). Difficulties in combating modest threat attributed in large part to lack of training
	Heat and Smoke Management Tests (1992)	More manpower needed for manual desmoking. Personnel should be general in their duties.	Less confusion when a single hose team attack used (use Hose Team #2 as back-up when needed)	Distributed DC stowage demonstrated. The use of more manual equipment does not necessarily result in improved performance	Consider reducing the minimum manning of IET. Preplanning needed for 'manual' smoke management.
	Firefighting and Doctrine Control Equipment Evaluation Tests (1996)	Rotation of personnel to relieve direct attack teams.	Combination indirect and direct attacks effectively demonstrated	Many failures with COTS and portable indirect fire fighting tools.	Improvements to SCBA design
DC-ARM Test Series	DC-ARM (1998)	DC Manning level of 70 people in Repair 2, Repair 3 and DC Central is considered reasonable	Decentralized DC command structure		Develop systems to automate DC functions. Refine threat characterization and performance goals for DC ARM.
	DC-ARM (2000)	Optimization of manning was not a focus. Demonstration focused on technology. Refined RRT. Emphasis on indirect attack of PDA	DCA experienced "information overload". Limitations associated with relying on DCA to give specific instructions to individuals. Need doctrine for semi-automated and automated systems.	SCS improved situational awareness. Identification of PDA and boundaries. Water mist effectiveness. Fire main control very effective - improvement.	Transition from remote-manual to fully automated systems with manual override.
	DC-ARM (2001)	DC manning level of 45 people evaluated with automated DC systems. Manning and systems proved effective for demonstration.		Refined SCS and sub- systems provided DCO with good situational awareness. Sub-systems were automated and directly interfaced with the SCS.	SCS needs work. 45 person manning organization effective when provided with adequate training. Good communications are still key.

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